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I would like to share with you one of the most exciting new products ever developed by Meade® Instruments. It is called the Deep Sky Imager,™ and represents a revolutionary breakthrough in CCD astro-imaging.

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By using proprietary methods (patents pending) Meade's engineers corrected the deficiencies that exist in current CCD digital imagers. For example, consider our extraordinary efforts to increase picture quality by suppressing electronic noise. This is accomplished by turning off the internal power supplies and running the camera on stored energy, while concurrently measuring the intensity of light captured during exposure. To further improve image quality we separated analog and digital circuits into opposite metal chambers with two ground planes. The Deep Sky Imager does not compress the data coming from the sensor, and uses a full 16-bit analog-to-digital converter to enhance picture depth, contrast and dynamic range. Finally, a unique method was devised to reduce image sensor temperature by directing heat generated by circuits away from the CCD sensor. The result: less noise and the ability to take longer exposures.

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NGC891 Caldwell 23

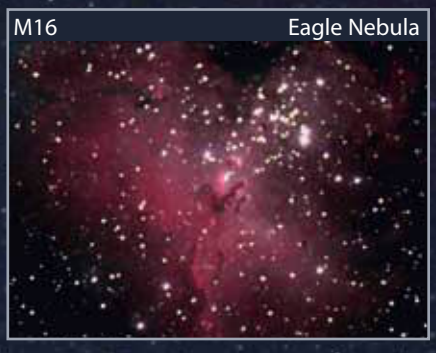
M27 Dumbell Nebula

M51 Whirlpool Galaxy

M13 Hercules Globular Cluster

All images were taken with a Meade 8" LX200™GPS using Meade's Deep Sky Imager. Total exposure time was 10 minutes (20 exposures at 30 seconds each – automatically stacked). All images were processed using Meade's AutoStar Suite software.

M16 Eagle Nebula



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october 04

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RICK SARRICA

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ON THE COVER
Alluring to observers and spacecraft alike, Saturn poses for the approaching Cassini. Taken May 7, 2004, from 17.6 million miles (28.2 kilometers) away, *two* narrow angle camera images were needed to capture this end-to-end view. On October 26, Cassini will pass 750 miles (1,200 km) from Saturn's largest moon, Titan. NASA/JPL/SPACE SCIENCE INSTITUTE

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BY DAVID J. EICHER

Cassini's long, strange trip

Saturn always has fascinated people

like no other planet. One small telescope gaze at the ball surrounded by its orange rings usually bedazzles everyone — at least for one night. So it has been with high hopes that astronomers have waited for 7 years as the Cassini spacecraft sped to the Ringed Planet. Now it will undertake a 4-year exploration of Saturn and its moons. Cassini will make the first in-depth study of the most beautiful planet in the solar system. The Voyager spacecraft whizzed past Saturn and its moons 25 years ago; now Cassini will slow down to really understand what makes Saturn tick. Senior editor Rich Talcott's story, "Cassini reaches Saturn," on page 38, showcases the first results from Cassini's flyby of the moon Phoebe; the initial exploration of another moon, Titan; and the first tantalizing, close-up images of the rings. The pure science will follow — data will be pouring in so fast that it will outstrip astronomers' ability to interpret it by light-years. Early next year, we will experience the most dramatic moment of the mission when the European Huygens probe drops onto Titan's surface, taking measurements all the way down until impact.

So far, two exciting windows have been opened into the past. First, Phoebe has shown that it is a truly ancient body. It probably originated in the outer solar system's Kuiper belt of asteroids, rather than starting in the main asteroid belt and migrating outward. Because such primitive bodies act as frozen time capsules, Phoebe will allow astronomers to study conditions in the early solar system. Second, Titan's thick atmosphere and primitive surface chemistry may give astrobiologists and planetary scientists a look at conditions similar to those on early Earth. The discoveries and surprises will undoubtedly abound over the coming months; Rich's story gets us going with the first, exciting results.

ASTRONOMY'S 2004 TRANSIT OF VENUS group finds antiquity at the Giza Plateau near Cairo.

VIC AND JEN WINTER/ASTRONOMICAL TOURS

Ray Villard's story, "Beyond Hubble," on page 32, explains the nature of the real successor to the Hubble Space Telescope. After Hubble falls into the ocean, the James Webb Space Telescope will be the next major orbiting observatory launched. It will see the cosmos in the infrared, however: The story of Hubble's true successor, the Very Large Space Telescope, awaits in Villard's compelling preview.

In June, *Astronomy* sponsored two tours to see the transit of Venus from Africa, one from South Africa and one from Egypt. The story of those adventures appears in "Venus transit tours" on page 76. In the image above, our Egyptian group of 68, led by Vic and Jen Winter of Astronomical Tours, poses in front of the legendary Sphinx and pyramids alongside the Nile.

Yours truly,

David Eicher
Editor

Astronomy

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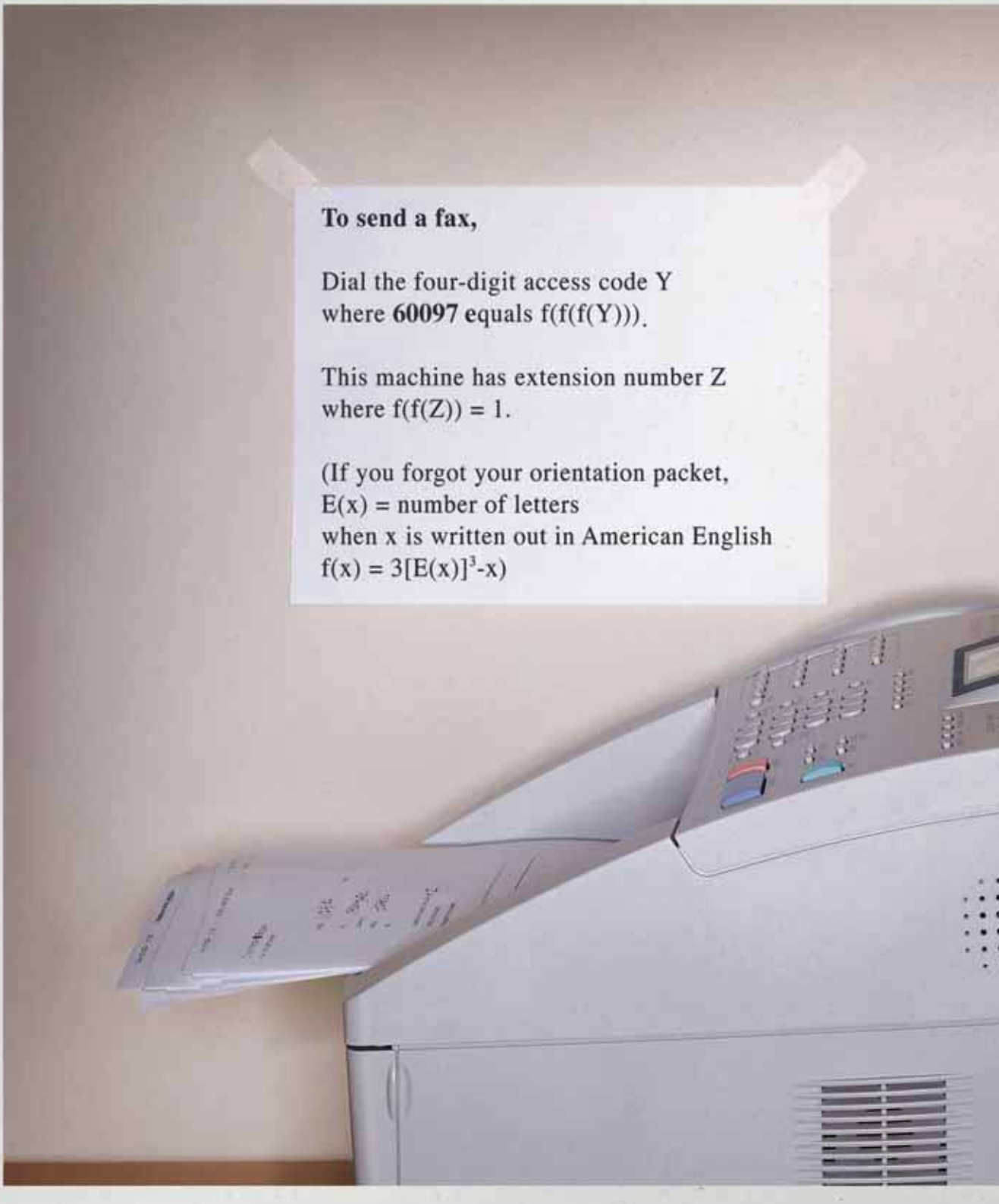
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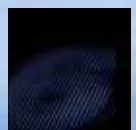

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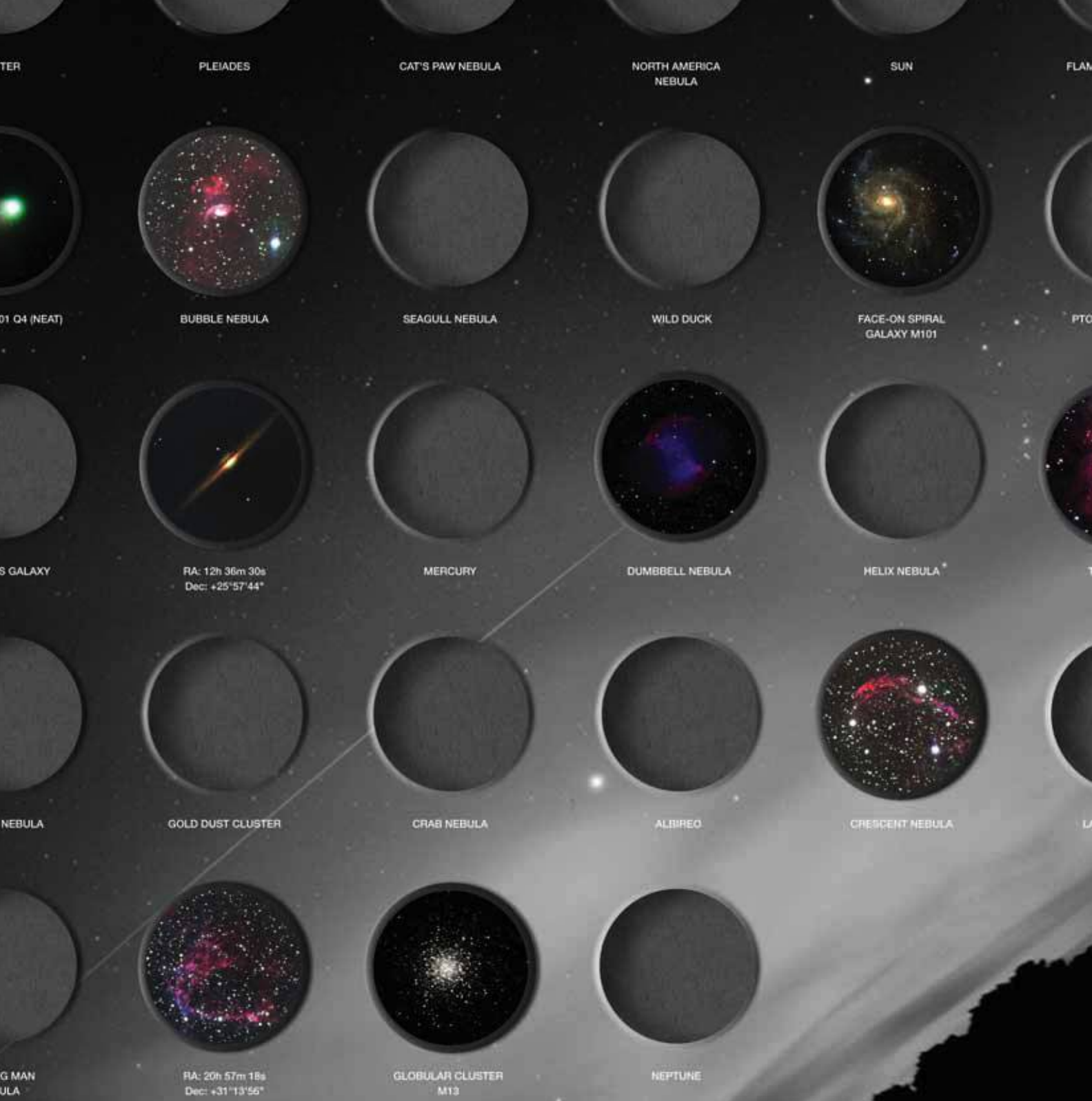

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To the Moon and back

"Did NASA fake the Moon landing?"

(July 2004) was a great read. Ray Villard did a nice job bringing up all the facts on why it was impossible to fake it (although I have one coworker who still argues that it was) and injected the right amount of humor into the piece that had me laughing out loud a few times. Sadly, I fear, the only way to prove to conspiracy hoaxers that NASA did, in fact, land on the Moon would be to land a manned — or even a robotic — lander near one of the Apollo landing sites and photograph it. Of course, they would just say that was staged, too. — ED SULESKY, FRIDLEY, MINNESOTA

HARRISON SCHMITT, Apollo 17 lunar module pilot, poses with the American flag. Schmitt and mission commander Eugene Cernan, who took this photograph, were the last men on the Moon, in 1972. NASA

Ever since the Apollo program, conspiracy theorists have tried to claim that the landings never happened. Early on, I came up with this rebuttal, which everyone seems to overlook: We were in a fierce space race with the Soviet Union. They were watching our every move and monitoring all our telemetry. Had we faked anything, they gleefully would have told the world. It was easier to go to the Moon than to trick the Russians. — BOB SCHUMACKER, MACON, GEORGIA

Indeed, the liftoff of the lunar module was documented visually from the lunar rover, but not by film, as you mention. This was done by television downlink, as any film documenting the liftoff would have just missed its ride home. This is the same remote-controlled TV camera that gave us such stunning video images throughout the rest of the mission(s). — RICHARD NEWTON, MIDDLETON, MASSACHUSETTS

It seems to me you were playing to the wrong audience with this article. What good does it do to try to convince people who are already convinced? If the object was to reach crackpots who believe we didn't go to the Moon, then the article would have been better placed in *The National Enquirer*. The fact that FOX went for this scam is dismaying, to say the least! — GENE STUCKEY, ROANOKE, VIRGINIA

Impossible feat?

I had to chuckle at Robert Pappalardo's assertion that the deeply buried seas of Callisto are "forever inaccessible to humans"("Jupiter's water worlds" July 2004). It brought back memories of 1969, when, at age 12, I first watched astronauts walk on our own Moon.

Fascinated by that feat, I found a book about the Moon in my school library. The book had been published 30 years earlier, and its opening sentence was, "Although it is impossible that Man shall ever go to the Moon . . ." It is, of course, impossible that man shall ever fly, or be able to find the *Titanic* at the bottom of the sea. Or is it? — DANIEL JOHNSON, EVANSVILLE, INDIANA

Shuttle safety revisited

The single most important thing the Space Shuttle program has accomplished is putting the Hubble Space Telescope in orbit and maintaining it. While in the Air Force, I worked as a Space Shuttle Flight Controller for almost 5 years and know firsthand that it is a dangerous operation. When I read about Ed Weiler, NASA's associate administrator for space science, (Interview, July 2004) "offending" his astronomy colleagues while insisting we must let Hubble die for safety reasons, I thought that was disingenuous! — MAJ. JOHN GREER, USAF (RET.), ROCKFORD, TENNESSEE

Correction

David Lasser's *Conquest of Space*, which was cited in "Visions of space" (July 2004), was published in 1931. Willy Ley's *Conquest of Space*, which was illustrated by Chesley Bonestell, was published in 1949. — *ASTRONOMY* EDITORS

We welcome your comments. Send letters to Astronomy *Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY BOB BERMAN

Behind the galaxy

The Andromeda Galaxy, overhead this month from much of North America, is no weirder than your average cheeseburger. So why talk about it on a page that usually explores strange things? Simple: If you don't go into the oddities of that bright naked-eye galaxy, it probably shouldn't be shown to anyone.

Sure, *we* like observing M31. Through binoculars, its familiar shape is obvious. Dust lanes appear with any good scope, as do its little blobby companion galaxies. Wonderful stuff. But sadly, friends are not likely to agree. Andromeda is a familiar name, and they've seen glorious photos of it. Only if you prep them with mouth-watering stories will their excitement overcome the brutal fact that M31 looks smudgy and ill defined.

Start with its location in the sky near the Milky Way. Of course, it couldn't possibly sit *within* the band of the Milky Way because our own galaxy blocks out everything lying beyond. That it appears so near the Milky Way means it was a close call whether we would get to see it at all. Our galaxy's disk aims almost in Andromeda's direction, and Andromeda just barely clears the foreground muck and crud.

In fact, as our galaxy rotates, we'll eventually be carried to the far side of the carousel, where the big bulge at the Milky Way's core will obscure Andromeda totally. Then, it'll vanish for many millions of years. That no-M31 epoch will begin in roughly 100 million years. Andromeda is the only major galaxy that comes and goes depending on where we happen to be as our galaxy performs its grand 240-million-year pirouette.

With the naked eye, and especially through binoculars, it's obvious that M31's flat disk is oriented *nearly* sideways. A shame. Its orientation, 13° from edgewise, is what makes it a smudgy mess through backyard instruments.

Strangely enough, that's the same orientation our Milky Way would display to any Andromedans using a nice telescope to look back at us. When you think about Andromeda's location in the sky near the Milky Way, you realize, yes, they must see us *nearly*, but *not exactly* edgewise.

In fact, maybe Andromeda doesn't exist at all and, instead, there's a giant mirror out there and we're merely looking at ourselves! This very theory was proposed by no less than Henry Neimark, a mental patient at Bellevue Hospital.

Andromeda also was where the unpleasant, but brilliant, Edwin Hubble first detected extragalactic stars, proving the universe to be far larger than previously known. Realizing this in the 1920s, he and others decided that instead of "Andromeda Nebula" — its popular name for centuries — M31 should be called an "island universe" — a fabulous term for a separate starry empire. Too bad it didn't stick. Instead, it was decided that these entities would be termed "galaxies."

Reason: Astronomers wanted to retain the *creamy* theme of our own Milky Way, describing the distant star-cities as galactic because "lactic" means "pertaining to milk." So the entire universe was to be considered some sort of vast dairyland, and it all started with Andromeda.

Backyard scopes reveal the star-like glow of M31's nucleus. The Hubble Space Telescope split this nucleus in two, with the brighter component offset from M31's true center. At its heart lies the customary massive black hole that seems to occupy the center of all galaxies. Andromeda's may have the mass of 100 million suns.

The rest of the universe may be flying apart, but we and Andromeda will hang out forever thanks to our mutual gravitational grasp. Andromeda, though, is hurtling toward us at 60 miles per second (96.6 kilometers per second). So there's an excellent chance Andromeda, now 2.9 million light-years away, will collide with us when Earth is about twice its current age.

{ So the entire universe was to be considered some sort of vast dairyland, and it all started with Andromeda.

It's an *attractive* notion.

A galaxy's stars lie so far apart that none makes contact when galaxies slam into each other. Instead, one galaxy simply passes through the other. What a future sight in our sky! And there's always the chance that Sol will be among the many stars that gets yanked from one galaxy to the other. Imagine — our return addresses may someday say "Andromeda" instead of "Milky Way." Later on, both galaxies may combine into one super-sized, globular-shaped elliptical galaxy.

No matter what happens, our fates are entwined forever. That's a story to share before passing around the binoculars.

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BY GLENN CHAPLE

Gettin' shapes

Are you in *shape* to go outside

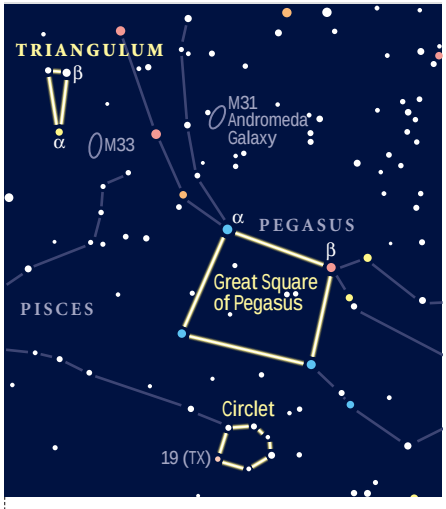
tonight and view the shapely sky objects I'm featuring this month? I'm talking about the classic geometric shapes formed by stars in the night sky — you know — squares, circles, and so on. Some are entire constellations, like Triangulum the Triangle. Others are either asterisms, or parts of constellations, exemplified by the "Circlet" of Pisces. A sky shape may even be made up of stars from two different constellations.

Consider the Great Square of Pegasus. Three of its stars belong to the Winged Horse, but the fourth is the alpha star of Andromeda. All three of these sky shapes are currently visible after sunset (see the illustration to the right).

"Great" in size only (the magnitudes of this quartet of stars range from 2.0 to 2.8 — second-class citizens as stars go), the slightly lopsided Square is nevertheless an imposing sight in the barren-looking autumn sky. The Great Square is a useful guidepost for locating nearby constellations and sky objects. A year ago ("Beyond the Milky Way," October 2003), we showed you how to use Alpha (α) Andromedae (the top left star in the Square) to find M31, the Andromeda Galaxy.

The Great Square is useful for pointing out other constellations and also can serve as an indicator of the *transparency* of the night sky. "Transparency" is the term astronomers use to describe night-sky clarity. Determined by a number of factors, such as atmospheric dust, haze, invasive moonlight, or light pollution, transparency changes from night to night — even hour to hour. If transparency is good, you'll see faint naked-eye stars. Binoculars and telescopes will reveal much greater detail in deep-sky objects than can be visible on an average night.

How many naked-eye stars can you see within the confines of the Great Square? If transparency is poor, as it might be in an urban area, you'll have trouble seeing even the Great Square. The finder chart on this page plots four stars inside the Great Square — all visible on an evening of average transparency.



THE GREAT SQUARE OF PEGASUS and the other shapes can be found using this finder chart.

ASTRONOMY: ROEN KELLY

Live in a remote rural area? As long as you're observing on a clear night when the Moon isn't lighting up the sky, you have a shot at picking out more than a dozen stars inside the Great Square.

You'll need reasonably transparent skies to see our next shape — the Circlet of Pisces. As the finder chart above shows, it's located a stone's — er, *meteoroid's* — throw below the Great Square. The most recognizable part of Pisces, the Circlet, is made up of about a half dozen 4th and 5th magnitude stars arranged in a 5° by 7° oval. (Hey, the Square wasn't perfect. Neither is the Circlet.) If you survey the Circlet with binoculars, you might stumble on a reddish star on the left (eastern) end. This is the star 19 (TX) Piscium. To see its ruddy color well, you'll need to hold those binoculars steady.

We've seen a square and a circle. Wanna go for the Triangle? No problem. From Beta (β) Pegasi at the top right corner of the Great Square, trace an imaginary line to Alpha Andromedae (top left), then extend it about one-and-a-half times beyond. This should bring you close to the alpha star of Triangulum. Not to be confused with the Summer Triangle, which we explored in August, Triangulum is a rather small and obscure stellar trio. The illustration to the left shows the location of the galaxy M33 is not far from Alpha (α) Trianguli. If you're an astronomical newcomer, M33 will prove to be a difficult naked-eye target. It's bright (magnitude 6.4) as galaxies go, but the light is spread over an area twice the Moon's apparent diameter. This makes M33 an elusive target, something you won't want to tackle unless skies are extremely transparent. In a future edition of this column, we'll show you how to notch this galaxy.

Don't forget about the Orionid meteors after midnight on the 21st and the lunar eclipse one week later. Try a Great Square star count at the beginning of the eclipse, while the Full Moon is still bright. Then count the stars again during totality, when the Moon's light is substantially dimmed. You won't believe the difference!

Questions, comments, or suggestions? E-mail me at gchaple@astronomy.com if you want to share your thoughts with the staff at the magazine. You also can contact me directly at gchaple@hotmail.com.

Next month: We'll take a close-up look at the constellation Cassiopeia.

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BY WILLIAM SCHOMAKER

Jesús Maíz-Apellániz

When he's not busy calibrating the Hubble Space Telescope's Imaging Spectrograph, interstellar gumshoe Jesús Maíz-Apellániz prefers chasing a particular brand of unruly, celestial vandals across the universe. Maíz-Apellániz, a European Space Agency astronomer at the Space Telescope Science Institute in Baltimore, specializes

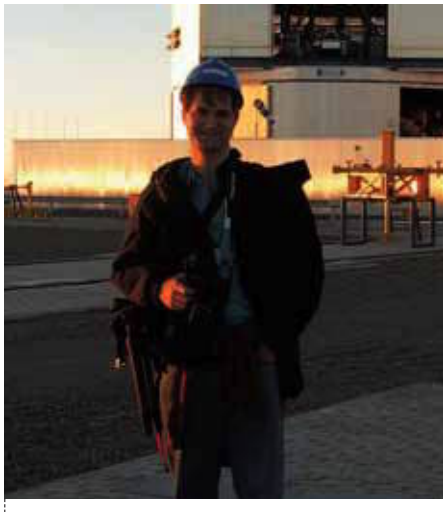
in the study of supernova-producing, loose clusters of bright, young stars called OB associations. Named after the hottest and brightest stars (spectral types O and B) that predominate these populations, OB associations are notorious for their destructive impact on the interstellar medium (ISM) via supernova explosions and stellar winds.

Maíz-Apellániz recently gained renown for his introspective analysis of the formation of the Local Bubble — a 600-light-year-wide supernova-induced cavity that surrounds our solar system.

How did you crack the mystery of the Local Bubble's formation?

By the time I had started working on the problem, it was already pretty clear that the Local Bubble is too large to have been created by a single supernova explosion, yet there didn't seem to be any clear consensus about what population of stars may have been responsible for its creation. The nearest candidate group, an OB association called Scorpius-Centaurus (Sco-Cen), lies just outside the Local Bubble.

Knowing that stars move through the ISM, I thought that it might be a good idea to find out where this association had been in the last 10 million years. So I compiled some data and discovered that Sco-Cen, part of it at least, would have been inside what is now the Local Bubble. And models predict that six supernovae would have exploded in that region in the last 10 million years, which would put it in the right place at the right time for creating the Local Bubble.



JESÚS MAÍZ-APELLÁNIZ juggled three frames of reference to solve the mystery of the Local Bubble's formation. RODOLFO BARBÁ

This was a big discovery, right?

Well, calculating past positions of stellar associations isn't trivial. You need to take all of the equations of motion into account, but you also have to be careful to know which frame of reference you are working with. In all, we have three frames — the frame of reference of the galaxy, the frame of reference of the Sco-Cen association, and the frame of reference of the Sun. Both Sco-Cen and the Sun are moving with respect to the galactic frame of reference. And, of course, the galaxy is rotating, so it's actually quite a headache.

Does Sco-Cen continue to create bubbles?

Yes. The entire Sco-Cen association is moving into a part of the galaxy we call Loop I — adjacent to the Local Bubble. I calculate that [about] 30 or 40 more supernovae will explode within Sco-Cen in the next 20 to 30 million years, meaning we can expect a very large "superbubble" to be created right next door.

What will happen to the Local Bubble?

As supernovae explode, they create shock waves and additional pressures, which sweep out the ISM and create these bubbles. But once everything cools down, pressure decreases and the bubble collapses. If our Local Bubble is young, but not extremely young, meaning that it was formed between 2 and 6 million years ago, and in the last 2 million years we haven't had any supernovae because all of this association is moving away, then it should mean that in about 2 million years, we will find ourselves back in the thick of a denser part of the ISM.

How do associations in other galaxies compare to Sco-Cen?

Sco-Cen is a typical association for our galaxy, which is pretty average in terms of star formation. But when you go to other galaxies, you find associations that are much larger. Sco-Cen might have formed with a total of 10 O stars. One of the objects that I studied in my thesis, NGC 604 — which is an OB association in M33 — probably had more like 300 or 400 O stars. Some of these giant associations, once given enough time, can create gigantic superbubbles that span thousands of light-years.

But why some galaxies are better at producing stars than others is one question that is far from being answered.

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Whirlpool Galaxy – Taken with the SVP 100ED EQ at prime focus. Two stacked exposures from a Canon Digital. Courtesy of Bryan Cogdell.

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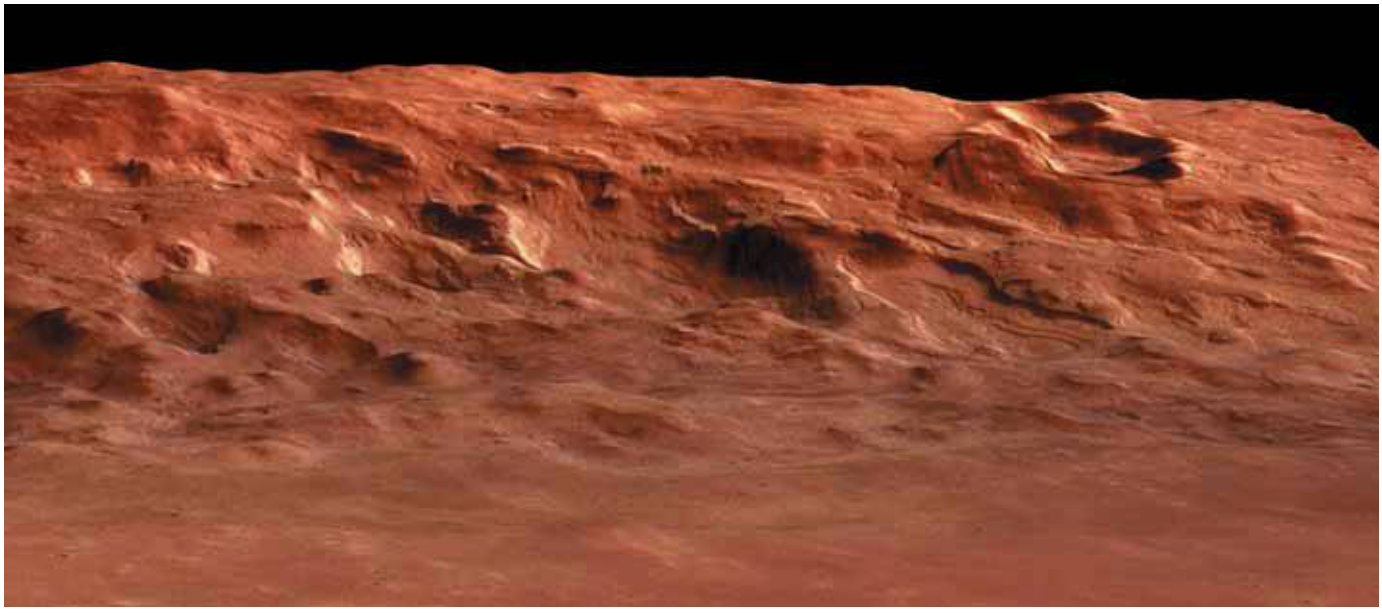
ULTRAVIOLET IMAGES TAKEN WITH HUBBLE show that Eta Carinae is a binary star system with a 5.5-year period. As the stars orbit each other, their ultraviolet light throws varying shadows on nearby dust and gas clouds.

news 10

Read all about it: snatching extraterrestrial samples in mid-air, the Large Magellanic Cloud's messy past, hitting an asteroid to see what happens, and a big solar blast that reached the solar system's edge.



A GIANT IMPACT made the Hellas Basin on Mars. The perspective view (above) combines a Mars Express image (below) plus stereo topographic data. ESA/DLR/FU

24 Mapping solar blasts in three dimensions

26 Brown dwarfs are born like ordinary stars

28 Galaxies that are old before their time

30 Mystery Mars rock

PLANETARY EXPLORATION

Rim shot

The northern rim of the Hellas impact basin in Mars's southern hemisphere shows deep canyons in images taken by the High Resolution Stereo Camera on Mars Express.

The basin is 1,400 miles (2,300 kilometers) across and 6 miles (9 km) deep. A small valley network seen at extreme left in the image (right) seems to have been carved by flowing water. — ROBERT BURNHAM

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SOLAR ASTRONOMY

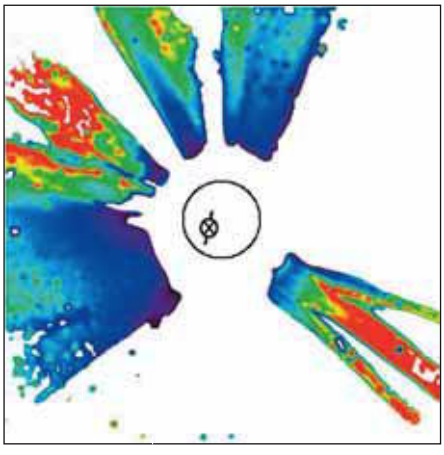
Solar bursts mapped

Coronal Mass Ejections, or CMEs, are outbursts of billions of tons of electrified gas and charged particles from the Sun. If a CME strikes Earth, it can cause aurorae, disrupt communications, crash power grids, and even destroy satellites. Scientists have a valuable new tool to study these eruptions with the creation of the first three-dimensional CME image.

Two astronomers captured a sequence of three Solar and Heliospheric Observatory images and used the ratio of polarized to unpolarized light in them to measure how far from the Sun a streamer of gas had traveled. Outbursts erupt highly polarized and then become more randomly oriented as they fly from the Sun. The team saw Earth-directed CMEs resemble an expanding arcade of loops.

"We need to see the structure of CMEs in three dimensions to fully understand their origin and the process that launches them from the Sun," says Thomas Moran (NASA Goddard Space Flight Center), lead author of the study, published in *Science* (July 2, 2004).

Says Moran, "Views in three dimensions will help us better predict CME arrival times and their impact angles at Earth." — KELLY KIZER WHITT



OUTBURSTS OF ELECTRIFIED gas ejected from the Sun now can be studied in 3-D using polarization observations. Purple areas lie close to the Sun, red ones are 6 solar radii closer to us. ESA/NASA

The Genesis snatch

The first retrieval of samples from beyond low-Earth orbit in more than 30 years will occur September 8, if all goes well with the return of the Genesis capsule and its solar wind specimens. The final stage — capture in midair as a helicopter-borne trapeze snares the parasail lines of the descending payload — will conclude a remarkable and complicated space odyssey.

RECOVERING GENESIS calls for deft flying, seen here in rehearsal. The sample capsule descends by parasail but will be caught in midair because it likely would be damaged on landing. NASA

The 390-pound (210-kilogram) Genesis capsule isn't the first space vehicle to be caught in midair. In the 1960s, U.S. Air Force transport planes routinely snagged capsules descending with space spy film. Nor is the probe's atmospheric entry particularly difficult — it's coming in only a little faster than Apollo capsules did.

But its long journey took Genesis to the very edge of the Earth-Moon gravity well, four times the distance from which any spacecraft has ever returned to Earth.

The probe spent 30 months drifting around SEL-1, Sun-Earth Lagrange Point 1, which lies 1 million miles (1.6 million km) sunwards of Earth. There, its aerogel foam captured specks of the solar wind.

But any low-stress return trajectory from SEL-1 would have dived into the atmosphere in the middle of the night, making difficulties for recovery helicopters.

So earlier this year, the probe nudged itself away from SEL-1 and drifted around the rim of the Earth-Moon gravity field until it reached the opposite Lagrange point, SEL-2. From there, plans call for a rocket burn to drop it into a 2-week-long descending orbit that swoops past the edge of Earth, letting the probe fall out of the morning sky over Utah.

The Genesis "mother ship" does its final aiming in the last hours of the descent. If recovery is in doubt, it can raise its overflight altitude and miss Earth's atmosphere altogether, entering a parking orbit from which a new landing attempt can be made.

But once committed to the entry, the main craft spins itself up and then jettisons the 5-foot-(1.6-meter-) wide capsule. It fires the remainder of its fuel to dive into the atmosphere above the Pacific Ocean, to be incinerated safely.

The capsule, meanwhile, crosses the West Coast over Oregon, then flies across Nevada, finally reaching the 18 by 52 mile (30 by 84 km) Utah landing zone.

Midair recovery is preferred to minimize the chance of damaging the samples with a hard impact, or of contaminating them with Earth materials in the event of a capsule crack. In practices, the helicopter pilots have determined that the combination of their speed and the parasail descent rate should give them up to a dozen passes on which to snag the spacecraft. The capsule has a battery-powered radio beacon to guide ground searchers if the midair grab fails.
— JAMES OBERG

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THE TAU CETI SYSTEM, sometimes thought to be a possible home for life, is probably barren. Imaging studies show the star system is full of asteroids, comets, and debris. Constant giant impacts would be hostile for life.

GALACTIC ASTRONOMY

Globular clusters point to a tangled history for LMC

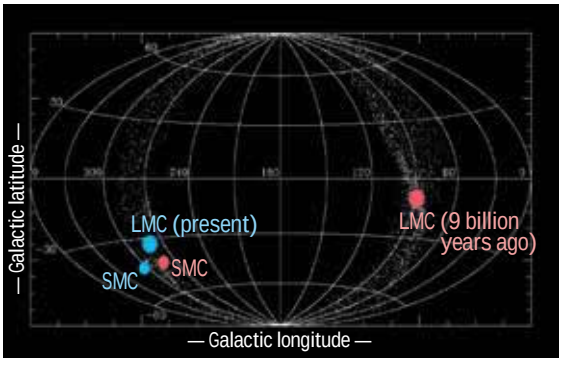
TIDAL ENCOUNTERS with the Small Magellanic Cloud gave the Large Cloud (above) a central bar and new globular clusters. E. SLAWIK

Nearly all globular clusters in the Large Magellanic Cloud (LMC), a satellite of the Milky Way, have ages of either 3 billion years or 13 billion years. Astronomers are puzzling over the 10-billion-year discrepancy.

Researchers led by Kenji Bekki (University of New South Wales, Australia) propose an answer rooted in the LMC's interactions with the Milky Way and the Small Magellanic Cloud (SMC). Their work appears in *Astrophysical Journal* (August 1, 2004).

The oldest globulars, they say, were born when both the Milky Way and LMC were born. The 3-billion-year-old population, however, began to form after the LMC had a close encounter with the SMC. This, plus subsequent encounters, stirred the LMC's gas and triggered the birth of the clusters. The interactions also gave the LMC its central bar.

Another relic of the tidal interactions is a large, diffuse stream of old LMC stars that circles the Milky Way. — R. B.



A STREAM OF STARS torn from the LMC in the last 4 billion years rings the Milky Way. UNSW

HIGH-ENERGY ASTROPHYSICS

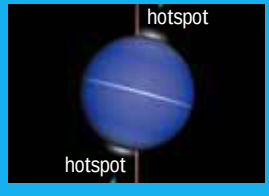
Pulsar has a hotspot

The neutron star Geminga has hot regions at its poles, a feature long looked for in such stars but never seen, according to Italian astronomers using the XMM-Newton X-ray satellite. Their report appeared in *Science* (July 16, 2004).

The team, led by Patrizia Caraveo (IASFC, Italy), found the hotspot is 400 feet (120m) wide at most. It may consist of one hotspot or several; its temperature is about 2 million kelvins.

"It's the smallest detail ever seen on an object beyond the solar system," says Caraveo.

The astronomers say the spot becomes hot when particles accelerated by Geminga's magnetosphere slam onto the star, heating it to emit X rays and gamma rays. — R. B.



GEMINGA'S hotspots remain visible as it spins. ESA, P. CARAVEO

STELLAR ASTROPHYSICS

Stellar runts *are* stars

A newly found pair of young brown dwarfs is shedding light on the nature of these objects. Kevin Luhman (Center for Astrophysics) used the 6.5-meter Magellan telescope at Las Campanas Observatory to see if brown dwarfs are miniature failed stars, super-size planets, or something else entirely.

The two brown dwarfs orbit each other more than 10 times farther apart than any other known pair.

"The mere existence of this fragile pair indicates that these brown dwarfs were never subjected to violent gravitational pulls," says Luhman.

"It's likely that these baby brown dwarfs formed the same way as stars, in a relatively gentle and undisturbed manner." — K. K. W.

A BINARY SYSTEM suggests brown dwarf stars have normal stellar births. CFA

EXTRAGALACTIC ASTRONOMY

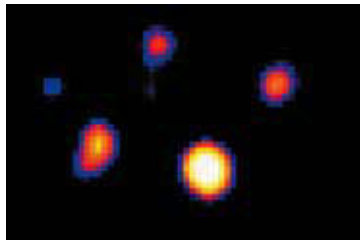
Chandra sees quadruple quasar

Scientists are analyzing a quadruple quasar seen by the Chandra X-ray Observatory. The Cloverleaf quasar lies 11 billion light-years away and appears as four discrete points of light due to gravitational lensing by an intervening galaxy.

A single star in the intervening galaxy has "microlensed" one of the four points, making it brighter than the others and providing details 50,000 times smaller than what would normally be detectable.

"The significance of the detection of microlensed X rays from the Cloverleaf quasar lies in the extremely small region that is enhanced by the microlens," says George Chartas (Penn State University), lead scientist on the study, published in *Astrophysical Journal* (May 1, 2004).

Says Chartas, "This lets us test models for the flow of gas around a supermassive black hole." — K. K. W.



LENSING LIGHT, an unseen galaxy's gravity turns one quasar into four and shows scientists minute details. NASA/CXC

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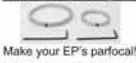

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THE 2004 EDGAR WILSON AWARD went to Vello Tabur and William Bradfield, both of Australia. The award, worth $20,000, is given by the Smithsonian Astrophysical Observatory yearly to encourage amateurs to discover comets.

STELLAR ASTRONOMY

Making stars more slowly

IONIZING RADIATION lights up the Orion Nebula — and astronomers are finding that it also slows the rate at which clouds of gas and dust collapse to make new stars. ESO

Positioned in the Milky Way 1,500 light-years away, the Orion Nebula (M42) is essential to the study of star formation. This active area has produced thousands of new stars during the past 10 million years. A new image captured by the European Southern Observatory is helping astronomers understand how new stars take shape within the nebula.

Led by Massimo Robberto (European Space Agency), the team used the Wide-Field Imager — a 67-million pixel CCD camera attached to the 2.2-meter scope at La Silla in Chile — to capture the nebula in several wavelengths. The filtered frames were combined to produce the false-color image above.

The team is studying the rate at which clouds of dust and gas collapse to make young stars — and how stars' locations in the nebula affect this. Astronomers think ionizing radiation from large, nearby stars influences star formation. Previous observations suggest new stars accrete material more slowly in the Orion Nebula than in more diffuse stellar nurseries. The new observations may validate this. — JEREMY McGOVERN

PLANETARY SCIENCE

ESA's Don Quijote to impact an asteroid

Don Quijote is the name of a two-probe asteroid mission. It is one of six being developed by the European Space Agency to study near-Earth asteroids.

Launching around 2011, one probe, Sancho, flies to the target body and orbits it, making observations while the other probe, Hidalgo, collides with the asteroid. Post-crash, Sancho continues to study the object.

The mission's purpose is to learn more about asteroids as physical bodies and to see how a massive object hitting an asteroid at 5 miles (10 km) per second affects its orbit. — R. B.

SANCHO will study an asteroid while a companion probe hits the asteroid at high speed. ESA

SOLAR ASTRONOMY

Sun blasts system

In October and November 2003, the Sun erupted in the most powerful storms ever seen.

During a 20-day period, blasts of charged particles blew off the Sun, raced past Earth, and by mid-July, reached the Voyager 1 spacecraft, nearly 9 billion miles (14.5 billion km) from the Sun.

The storms created havoc everywhere. They caused aurorae in Florida and drove space station astronauts into the return capsule, which offers extra shelter.

FAR FROM THE SUN, Voyager 1 still felt our star's fiery touch. NASA

At Mars, the solar blasts destroyed a radiation detector on the Mars Odyssey probe and stripped off part of the martian atmosphere. The process, scientists say, could have helped rob Mars of its water in ages past. — R. B.

GALACTIC ASTRONOMY

Galaxies that got old early

A glimpse into the early universe has revealed mature galaxies where researchers expected only newborns. The Gemini Deep Deep Survey (GDDS) analyzed spectra of 300 galaxies at an era when the universe was 3 to 6 billion years old.

The GDDS team, led by Karl Glazebrook (Johns Hopkins University), found highly evolved, massive galaxies, contradicting a theory of galactic evolution that says galaxies should form over billions of years. If accurate, the galaxies found by GDDS would not have had time to develop.

"There are obviously aspects of the early lives of galaxies that we don't yet completely understand," says Glazebrook. The team's results appear in *Nature* (July 8, 2004). — PAMELA ZERBINOS

MASSIVE GALAXIES have been found dating from an era too old for them to have formed already. NASA/STScI

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Thanks to Gary Palmer for these great solar images

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- Gary Palmer

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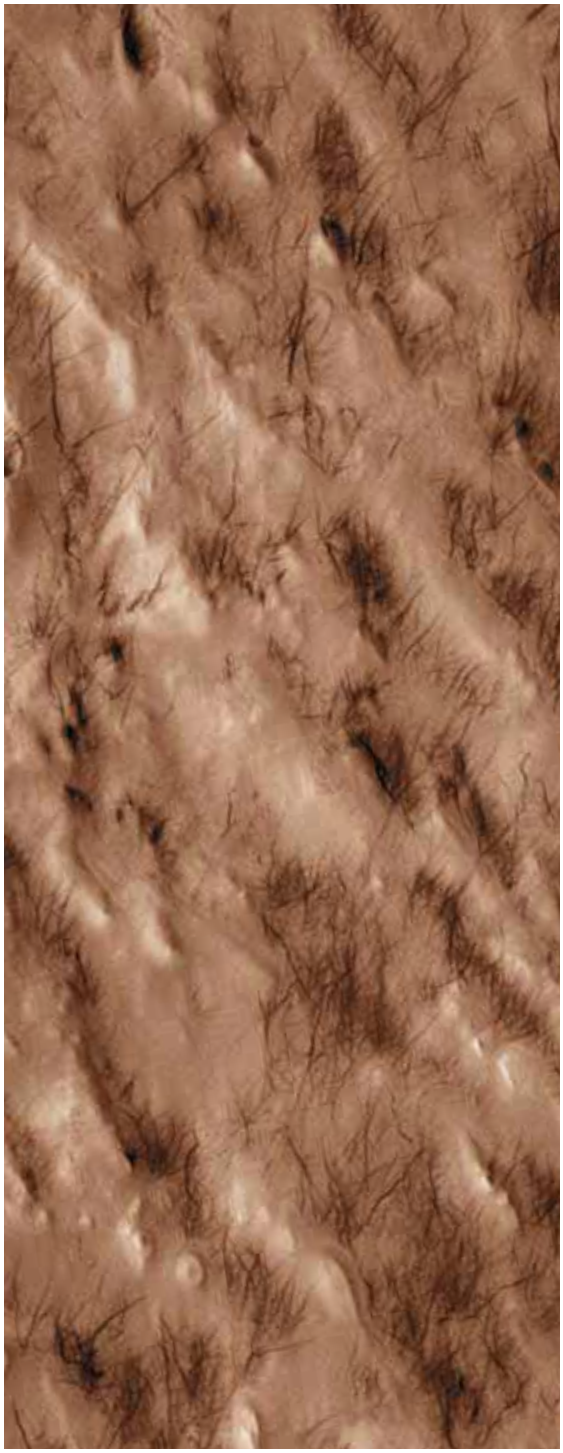
Dust devils in Argyre



DARK SCRIBBLES FROM DUST DEVILS cover a region of small, aligned hills on the floor of the Argyre impact basin. Martian dust is light in color, so when a dust devil passes, it exposes the darker rock underneath. This Mars Odyssey THEMIS image was taken near 47.6° south and 317° east. NASA/JPL/ASU/IMAGE 20040709A

METEORITES

Fast track to Earth

Jupiter's gravity shot debris to Earth from a collision in the inner asteroid belt 500 million years ago. The first pieces started arriving only 100,000 years after the smash, according to a group of scientists led by Philipp Heck (ETH, Switzerland).

Writing in *Nature* (July 15, 2004), Heck reports finding in a Swedish quarry ancient meteorites that scientists think originated when two large, primitive asteroids collided 500 million years ago, showering the solar system with L-type meteorites.

The smash occurred at 2.2 times Earth's distance from the Sun, where Jupiter's gravity strongly perturbs debris, shooting it out of the main belt.

The meteorites in the deepest (oldest) quarry layers spent about 100,000 years in transit, shown by how much neon and helium they contain, implanted by cosmic-ray strikes en route.

Heck notes that 100,000 years is the fastest delivery time on record. Most L-type meteorites took longer to reach Earth: 3 to 60 million years. — R. B.

MARS PHOTOJOURNAL

HOLES IN THE GROUND, but not impact craters, these pits near Rhabon Valles on Mars lie in a wide, shallow trough called a graben. The graben opened and the pits formed when this region of crust rose as the Tharsis volcanic bulge expanded. The image, sunlit from the lower left, is 1.9 miles (3 km) across. NASA/JPL/MSSS/IMAGE R05-01982

PLANETARY SCIENCE

"Razorback" rock is Mars mystery

Erect blades of some durable substance have been imaged by the rover Opportunity in Endurance Crater at a site called "Razorback" by scientists.

The blades' origin is unknown. But rover scientists suggest they formed when mineral-laden water seeped into the rock, depositing resistant veins in rock fractures. — R. B.

MARS ROVER Opportunity has found mineralized blades an inch or two high. NASA/JPL/CORNELL

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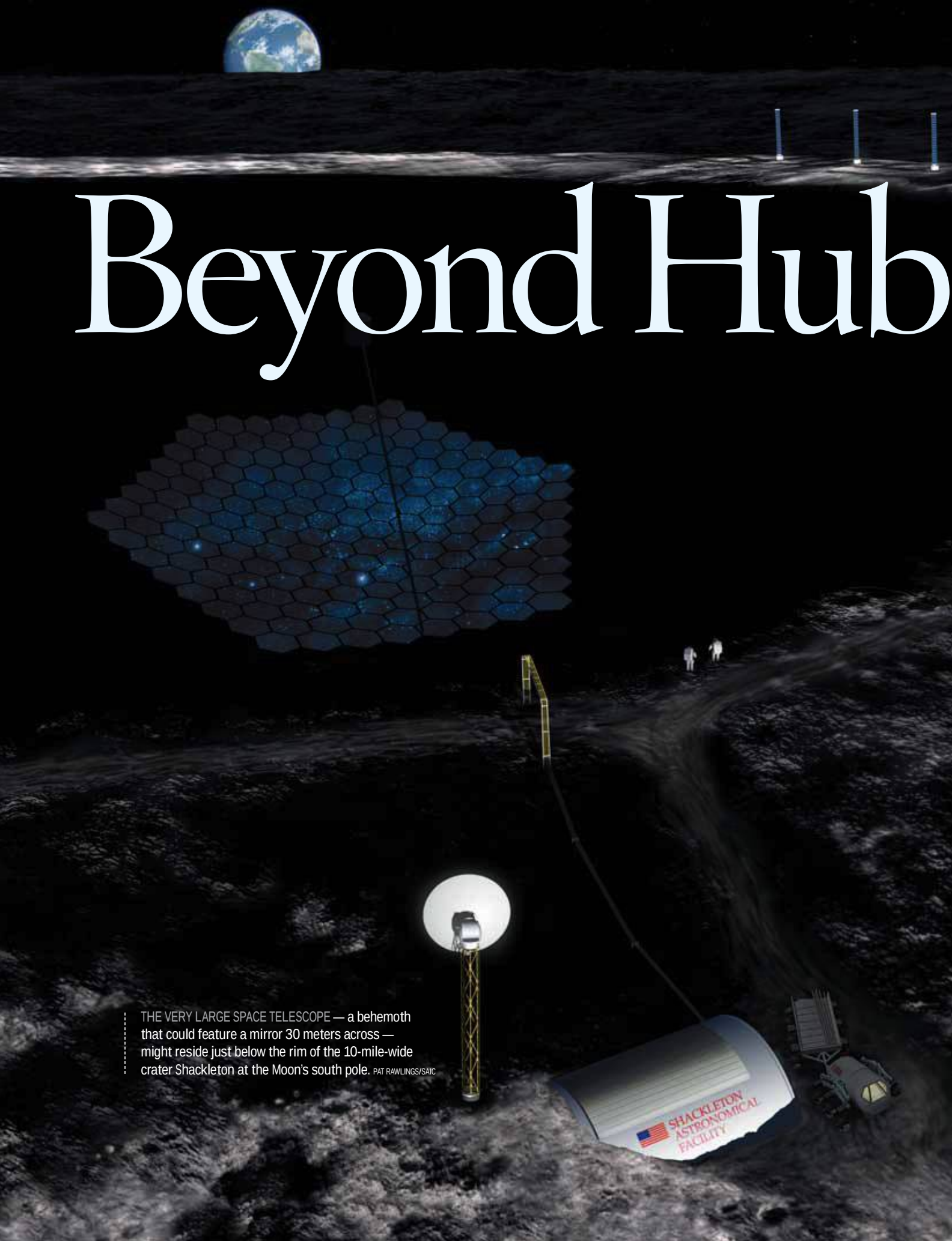
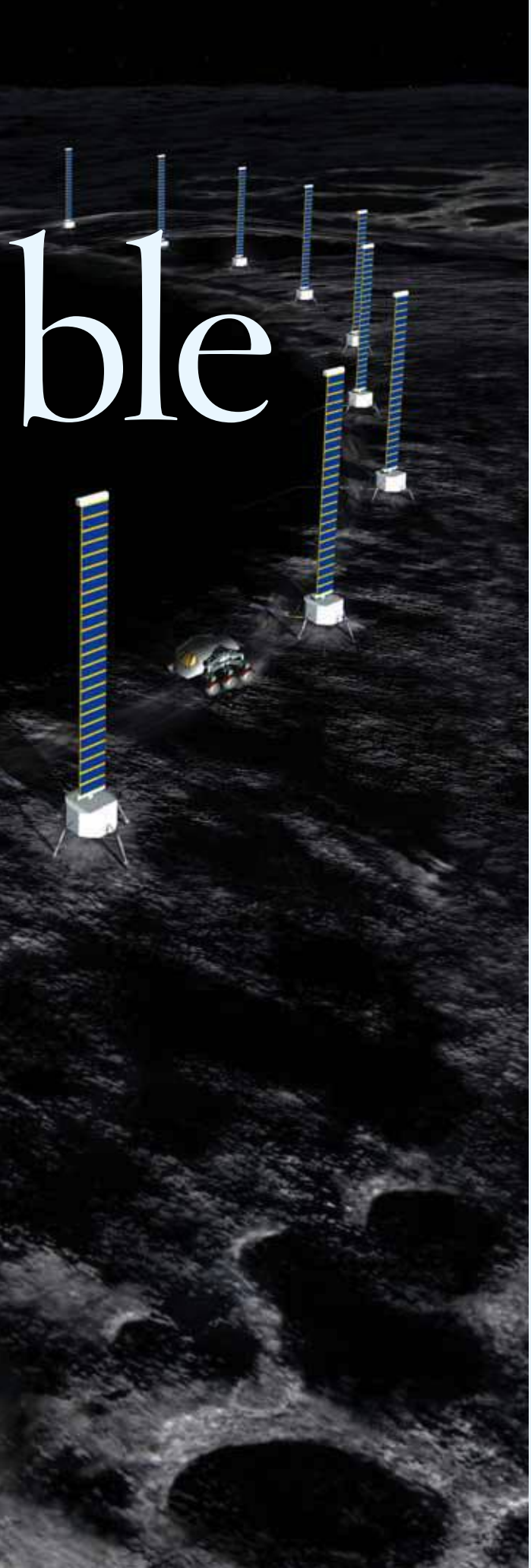


THE VERY LARGE SPACE TELESCOPE — a behemoth that could feature a mirror 30 meters across — might reside just below the rim of the 10-mile-wide crater Shackleton at the Moon's south pole. PAT RAWLINGS/SAIC



The Hubble Space Telescope's true heir has astronomers abuzz. This space-based observatory will show details 10 times sharper than Hubble does. /// BY RAY VILLARD

ROUGHLY A DECADE FROM NOW, A BRILLIANT METEOR will flash across the sky above the South Pacific Ocean. Breaking apart into several glowing streamers, it will look like an exploding aerial firework before fading away. A casual observer might think this is nothing more than an unusually bright fireball. But to the astronomy community, this will be akin to the mythical Icarus falling from the heavens. It will mark the fiery death of the legendary Hubble Space Telescope.

One million miles above this streaking $1.5 billion meteor, NASA's 6.5-meter James Webb Space Telescope (JWST) will pick up the gauntlet of high-powered space astronomy. It will peer even farther into the universe than Hubble, revealing the very first stars to emerge from the "Dark Ages" that followed not long after the Big Bang. But the Webb telescope *should* be considered the successor to the recently commissioned Spitzer Space Telescope, the infrared telescope that forms the final pillar of NASA's Great Observatories Program. The true successor to Hubble could be called the *Great-er Observatory*. The telescope has various names at present: Next Hubble Space Telescope, Next-Next Generation Space Telescope, or Very Large Space Telescope (VLST).

NASA has not yet funded, much less scheduled, the VLST. Instead, the agency is focused on returning humans to the Moon and eventually landing them on Mars. But the mission is the buzz among optical astronomers. They face the prospect that after Hubble breaks down — perhaps as early as 2008 without one more human or robotic servicing mission — there likely will be a decade-or-longer hiatus in precision space-based optical and ultraviolet astronomy.

The types of unique and exquisite research we've become accustomed to will grind down: stunning views of remote galaxies, characterizing dark matter and dark energy, analyzing the atmospheres of extrasolar planets, and studying dynamic phenomena such as the expanding debris around Supernova 1987A and the eruptive star Eta Carinae. What's more, when astronomers discover anything interesting in space that requires razor-sharp visibility — like the recent detection of a Kuiper Belt Object named Sedna — scientists and the public alike will lament: "If only we had Hubble . . ."

To rival Hubble's tremendous boost to optical astronomy, some astronomers say the VLST should provide a sharpness and sensitivity 10 times better than Hubble does. "The VLST will be to HST, what HST is to ground-based telescopes," says Holland Ford of Johns Hopkins University, the designer of Hubble's unmatched Advanced Camera for Surveys (ACS).

The goal of a tenfold improvement would require a mirror 25 meters in diameter, 2.5 times the size of the twin Keck Telescopes on Mauna Kea — currently the largest telescopes on Earth. As NASA develops the infrastructure for supporting an extended human presence in space, it should be increasingly feasible to build such a space

behemoth. With a fundamental need for this capability, the construction of a giant optical space telescope is more a question of *when* rather than *if*.

At 30 meters in diameter, the VLST's mirror would deliver images 12 times sharper than Hubble's and see objects 300 times fainter than the ACS, astronomy's premier camera today. In near-infrared light, the VLST would see stars and galaxies 25 times fainter than even the JWST will. The telescope's resolution at optical wavelengths would be 0.004 arcsecond, equivalent to seeing a soccer ball 7,500 miles (12,000 km) away.

The VLST could see tremendous detail in galaxies pretty much anywhere in the universe. That's because the angular sizes of galaxies do not change much beyond a redshift of one — a distance of approximately 7 billion light-years, or halfway across the universe — due to relativistic effects in our expanding universe. "Any details you can see at a redshift of one, you can go anywhere in the universe with comparable sharpness," says Doug Richstone of the University of Michigan. However, because the surface brightnesses of galaxies continue to dim with increasing distance, astronomers need ever-larger apertures to collect the faint light.

The VLST could monitor Cepheid variable stars to make distance measurements out to 800 million light-years. It could see stars like our Sun as far away as the Virgo cluster of galaxies. It could detect 1-billion-solar-mass black holes anywhere in the universe. Closer to home, the VLST could track the proper motion of all the visible stars in our galaxy.

In image sharpness and sky visibility, the VLST easily would outperform 30- to 100-meter ground-based telescopes planned for the next decade. The VLST would beat out the best of what adaptive optics could offer even a decade from now to un-blur stellar images. Like all space telescopes, the VLST would never have to contend with the practical limits imposed by Earth's turbulent atmosphere. It would enjoy pristine optical stability all the time, looking anywhere in space. The VLST would work especially well in the near-infrared part of the spectrum (0.7 to 2 micrometers), where the night sky glows brightly when viewed from the ground but not at all when seen from space.

For NASA to fund and build the VLST, the telescope's science goals must align, at least for the foreseeable future, with the agency's new prime mandate for deep-space astronomy: find and characterize Earth-like planets around nearby stars. The VLST is a logical follow-on to NASA's first generation of planet-hunting observatories. In 2008, the Kepler mission will look for planets transiting across a sample of 100,000 stars. In 2009, the Space Interferometry Mission will look for tiny wobbles induced by Earth-mass planets in the motions of 250 nearby stars. A decade later, the Terrestrial Planet Finder (TPF) will look for exoplanets tens of light-years from Earth.

THE HUBBLE SPACE TELESCOPE has enjoyed a long, successful life because it was designed to be serviced by shuttle astronauts. NASA

A 30-meter VLST fitted with a coronagraph to block a star's light would extend the search five times farther than the TPF's capability. For every single Earth-like planet TPF detects, VLST could find 100. These kinds of numbers will be necessary to begin assembling a statistically meaningful sample of Earth-like planets in our galaxy.

The VLST not only would image exoplanets but also would study their atmospheres spectroscopically at visible wavelengths. Oxygen, for example, can be measured only at visible wavelengths, making observations in the infrared crucial. In addition to observing these young galaxies, astronomers using the JWST will seek to understand the birth and formation of stars, determine how planetary systems form, and probe the nature of dark matter.

The JWST will sport a 6.5-meter primary mirror consisting of 18 segments. Currently scheduled for launch in 2011, it will be placed in orbit at the L2 Lagrangian point of the Sun-Earth system, some 1 million miles from Earth. During its expected 5 to 10 years of operation, the $800 million observatory should revolutionize our knowledge of the universe and pave the way for the Very Large Space Telescope.

— Richard Talcott

/// HUBBLE'S INFRARED SUCCESSOR

Astronomers have long dreamed about a successor to Hubble, a space-based telescope that would take observational astronomy to a new level. And they will get that — in a manner of speaking — with the James Webb Space Telescope (JWST). However, the JWST will be optimized for viewing in the infrared, not in the optical, part of the electromagnetic spectrum.

Scientists chose this wavelength region because of the expansion of the universe. To observe the epoch when galaxies formed, a few hundred million years after the Big Bang, astronomers have to look at objects receding from Earth at a good fraction of the speed of light. That speed shifts the radiation these objects emit to significantly longer wavelengths, making observations in the infrared crucial. In addition to observing these young galaxies, astronomers using the JWST will seek to understand the birth and formation of stars, determine how planetary systems form, and probe the nature of dark matter.

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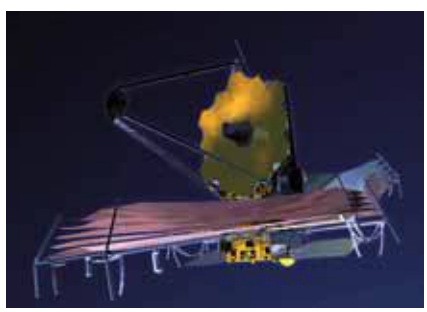
— Richard Talcott



THE JAMES WEBB SPACE TELESCOPE should be launched in 2011. Although some people think of it as Hubble's successor, the JWST is optimized for infrared rather than optical observations. NORTHROP GRUMMAN SPACE TECHNOLOGY

THE VLST'S ULTRA-SHARP VISION would render galaxies halfway across the universe with the same clarity as Hubble sees in nearby ones. This would allow astronomers to view galactic structure as well as study individual star clusters and giant regions of starbirth. The three images shown here simulate what a galaxy located 7 billion light-years away would look like when viewed through three different telescopes: an 8-meter ground-based telescope with excellent, 0.4" seeing conditions (left); the Hubble Space Telescope with its 0.1" resolution (middle); and the VLST with a resolution of 0.004". NASA/STScI

lengths, and even an exoplanet's atmospheric pressure can be deduced from the amount of reddening in the star's light as it passes through the planet's atmosphere. These measurements could be done out to a distance of 50 to 150 light-years from Earth, depending on the telescope's mirror size.

Spacecraft design

A 10-meter VLST might be built on the technology developed for the JWST. No current rocket booster can carry a payload as wide as a 10-meter mirror — the largest can accommodate something only half that size. If that doesn't change, the VLST would have to be unfolded in space like the JWST will be. NASA even might develop wide-body, heavy-lift boosters like the Apollo-era Saturn V that launched manned lunar missions. However, such rockets probably would be far too expensive for the VLST's budget.

Like the JWST, the VLST's primary mirror would be tiled with many hexagonal mirror segments. Unlike the JWST, the mirror would need to be shielded to block the glare of visible light from the Sun, Earth, and Moon. A free-flying telescope also would need optics designed to sense incoming light and automatically deform the mirror to maintain perfect, diffraction-limited performance.

The first suite of instruments could include an ultra-wide-field imager for taking galaxy surveys. It would seek distant supernovae to continue the quest to nail down the behavior of dark energy. Other instruments would include spectrographs and an optical coronagraph for hunting planets. All these instruments would be packaged into a single, integrated science module. The spacecraft bus would house the data storing and transmitting electronics, the pointing control system, reaction wheels, rocket thrusters, and gyroscopes.

A free-flying VLST likely would be deployed at the L2 Lagrangian point of the Earth-Sun system, where the JWST will be headed. The L2 point — one of a few gravitationally stable balancing points between the Sun and Earth — lies about 1 million miles from Earth, on an extension of the line that joins the Sun and Earth. A space telescope placed out there could not be serviced by astronauts. Hubble survived beyond the nominal 10-year lifespan for space observatories because astronauts tended it. But NASA has no plans to send astronaut repairmen out to the L2 point, a treacherous two-week journey with today's rockets. This means a VLST at L2 must be designed conservatively and with a lot of redundancy because it is inherently risk intolerant.

One logical way to make the telescope more risk tolerant than the JWST would be to service it robotically. Replacement parts could fly out to L2 autonomously. This concept envisions modules designed so that replacement units of electronics, computers, and attitude control systems could plug into the main spacecraft bus. Such a module would dock with the spacecraft bus and enhance or take over the tasks of aging or faulty components. The same concept also could be applied to the VLST's science instrument module, which might be built so it could be swapped out every few years with a replacement module.

The high frontier

A VLST larger than 10 meters in diameter would not be built without human construction and servicing capability. "The fiscal and technical risk becomes very large beyond a certain aperture," says Robert Williams of the Space Telescope Science Institute in Baltimore. "Larger telescopes will go beyond what could be accomplished without on-orbit assembly, testing, and servicing." A once-promising stepping stone was the idea of constructing the VLST at the International Space Station. However, the $60 billion station will be retired by 2016.

As a logical next step, NASA might construct a habitat, dubbed the "Lunar Gateway Portal," stationed at the L1 Lagrangian point of the Earth-Moon system. (This point lies on a line connecting the Moon and Earth where the gravity of the two bodies cancels.) Just a 2.5-day journey from Earth, it would be the first big "truckers' stop" in circumlunar space. The Lunar Gateway Portal (NASA no longer uses the word "station") could be an inflatable habitat

with docking bays, fuel reserves, workshops, and launch preparation facilities for sending manned and unmanned missions to the Moon and beyond. From the Portal, vehicles could reach any point on the Moon's surface within hours.

Presumably, mission crews would reach the Lunar Gateway Portal aboard NASA's touted Crew Exploration Vehicle, planned as the do-it-all, human-rated spacecraft to replace the space shuttle. Astronauts would live at the translunar construction shack for perhaps several weeks, staging any number of human and robotic missions. The Lunar Gateway Portal might be a platform where the VLST could be assembled and fully tested. A solar-electric-powered orbital transfer vehicle then would carry the telescope on the several-week journey to the Sun-Earth L2. The telescope would be towed back to the Portal for repairs and upgrades.

The Lunar Gateway Portal's primary purpose would be to launch cargo and manned lunar landers in support of NASA's return to the Moon. The first human lunar outpost likely would be at the Moon's south pole, which is more easily accessible because it would require less rocket fuel to reach from the Lunar Gateway Portal than from a direct Earth-launch, as now is being discussed for the Crew Exploration Vehicle.

The base would lie near the rim of the 10-mile-wide crater Shackleton (named after the early 20th-century Antarctic explorer Ernest Shackleton), which sits near the Moon's south pole. NASA's new charter is to establish a manned base on the Moon simply as an interim step toward a human mission to Mars. Nevertheless, Shackleton Ridge Base might offer a modest supporting infrastructure that could facilitate a project as ambitious as constructing a 30-meter VLST.

Untouched by sunlight for 4.5 billion years, the 1-mile-deep Shackleton crater should contain some of the most pristine material in the solar system. The Moon's orbit inclines to its equator only slightly, so some regions at the poles remain in permanent shadow. Water ice, oxygen, hydrogen, and maybe even nitrogen — all transported here by comets billions of years ago — could be harvested as resources for supplying the base with air and water.

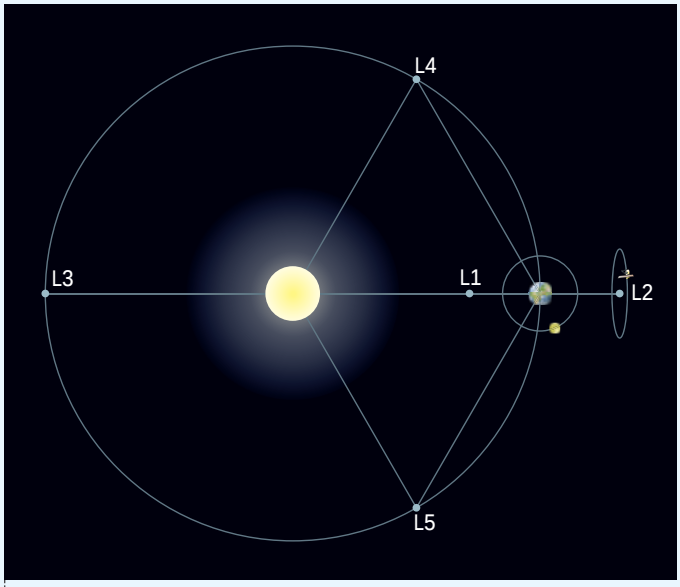
To make transportation economically viable, a lunar ferry would refuel at Shackleton Ridge Base with hydrogen and oxygen harvested from the frozen water reserves. The ferry would shuttle between the Moon and Lunar Gateway Portal. The lunar base camp would not necessarily be permanently occupied, but would serve as quarters for various expedition crews. One or more expeditions could erect and test a prefabricated 30-meter telescope. The undertaking could be justified as a construction project to practice for building structures on Mars.

A 30-meter telescope could be built just over Shackleton's rim, 150 feet down into the crater. The VLST would not be placed in the perpetual shadow deeper in the crater because, given the crater's 45° slope, it would be treacherous to reach. Instead, the telescope would be encased in a foldable cocoon to block sunlight.

A lunar VLST would not be hobbled by the three common ailments of space-based telescopes: failed gyroscopes, empty tanks of maneuvering fuel, and dead batteries. However, the Moon presents its own environmental challenges. Dust on the lunar surface is gritty and could damage machinery. The suits worn by the Apollo astronauts had mechanisms that were clogged with dust after just 3 days on the Moon. On a more encouraging note: The lunar ranging retroreflector mirrors left on the Moon more than 30 years ago continue to operate without any apparent signs of dust coating them.

The pointing and control system for a lunar VLST would be much simpler than for a space-based observatory. The Moon rotates very slowly, and pointing and stabilization would be no different than for telescopes on Earth. Issues of pointing and jitter that bedevil floating space observatories will go away. In the Moon's ⅙ gravity, the telescope could be built on a six-leg hexapod mount that would point by changing leg length.

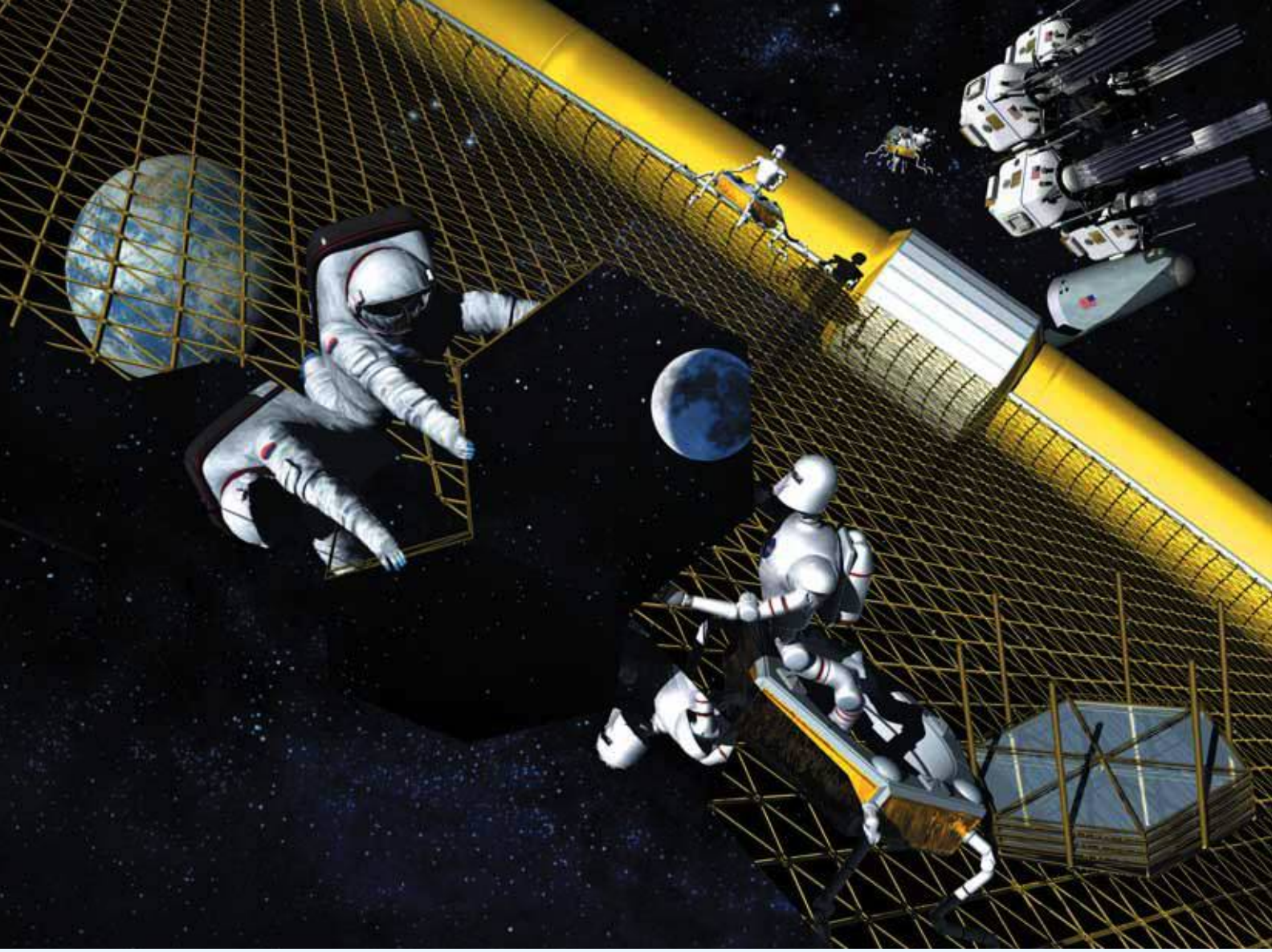
The Moon base's infrastructure also would include continuous power generation from solar panels on the crater's rim. They would bathe in sunlight for all but a few hours out of the year. Power could be beamed down as microwaves from the ridge to the VLST site. Moon-orbiting relay satellites would serve as switchboards in the sky to send commands and data between the VLST and Earth. The elegance with this approach is that the complex, automated planning and scheduling of observations



FIVE LAGRANGIAN POINTS mark stable positions in the gravitational spheres of two orbiting objects. The L2 point of the Sun-Earth system will be home to the James Webb Space Telescope, and possibly the Very Large Space Telescope. *ASTRONOMY:* RICK JOHNSON

> The VLST's resolution at optical wavelengths would be an astonishing 0.004 arcsecond, equivalent to seeing a soccer ball 7,500 miles away.

Ray Villard *is the public information officer at the Space Telescope Science Institute in Baltimore. His most recent article for* Astronomy *was "Did NASA fake the Moon landing?" in the July 2004 issue.*



THE VLST MIGHT BE ASSEMBLED at the Lunar Gateway Portal and then deployed in a stable orbit a million miles from Earth. NASA ARTWORK BY PAT RAWLINGS/SAIC

demanded by Hubble and the JWST wouldn't be needed. In principle, a lunar VLST could be operated in real-time like Palomar, Keck, or any ground-based facility. The only difference is that the "mountaintop" is 250,000 miles high.

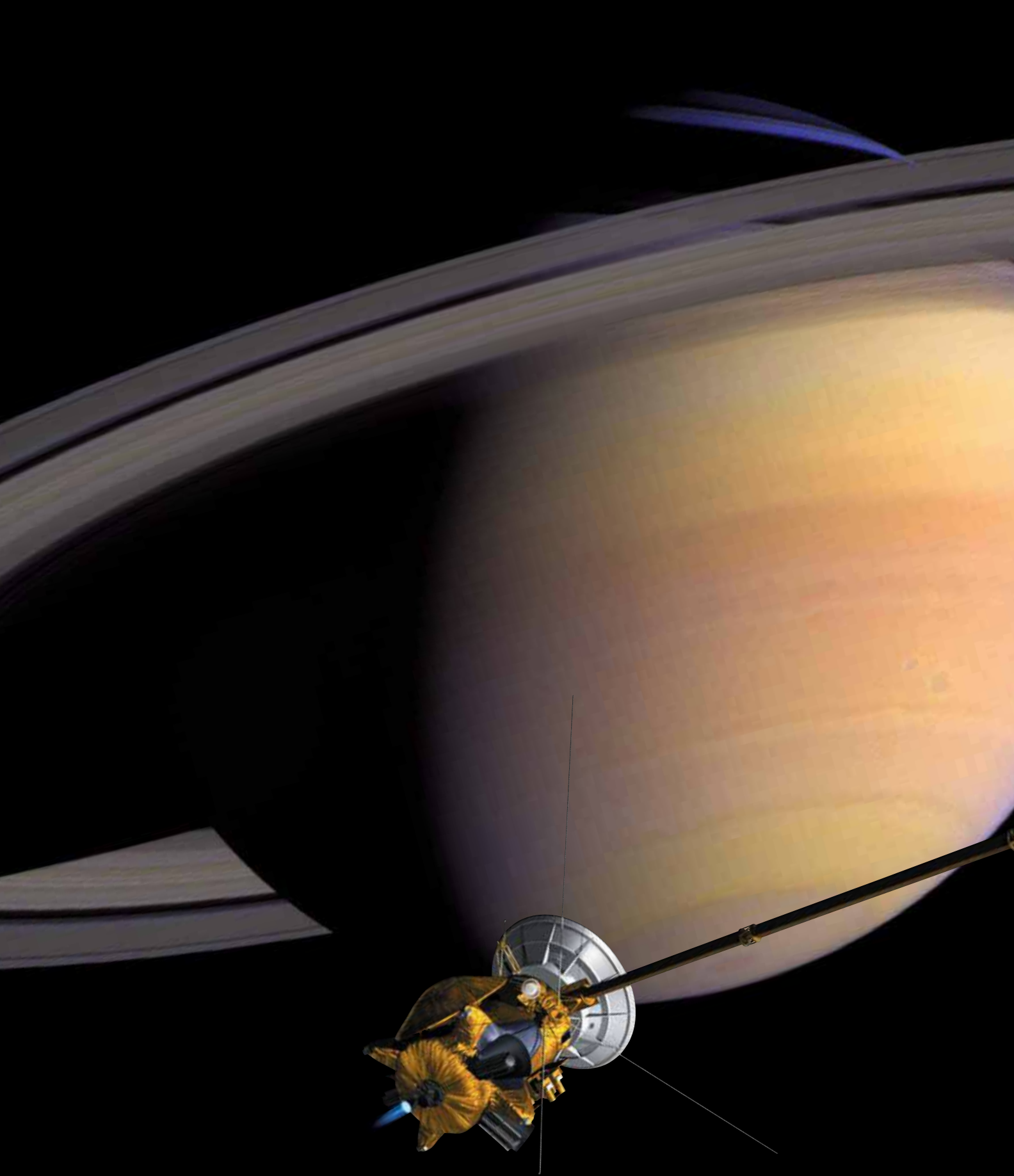
A telescope at the Moon's south pole would see only half of the celestial sphere — as opposed to a space-based VLST that could access the whole sky. Nevertheless, the southern sky is ripe for all kinds of astronomy. It is home to the galactic center and the stellar incubators within our satellite galaxies, the Magellanic Clouds. A lunar telescope could re-examine the Hubble Ultra Deep Field in the southern constellation Fornax. And it could examine some of the closest Sun-like stars that might harbor planets: Alpha Centauri, Epsilon Eridani, Tau Ceti, and 18 Scorpii.

A 30-meter telescope would entail such a capital investment that, with regular maintenance and upgrades, it should be capable of doing cutting-edge science for decades. Hubble enjoyed robust support from NASA because it was married to the manned space shuttle program. But as in any marriage, such a partnership boils down to "for better or for worse." When the space shuttle's days became numbered, so did Hubble's.

Equally sobering is the fact that there always will be a risk that a future administration or Congress may abandon support for a human presence on the Moon because of the danger, expense, or a fundamental shift in the nation's priorities. The proper blend of human, robotic, and teleoperated capabilities is an emerging paradigm for NASA. Humans might erect a lunar VLST, but robots would service it periodically long after humans have departed the Moon for Mars. If NASA support for the VLST should stop, the telescope could be designed to be mothballed — quite literally for decades — until some future generation, or even another nation, decided to return and operate it.

Whatever the final design, the VLST will inspire a new generation of skywatchers and dreamers, just as the Hubble Space Telescope did. Like Hubble, it will bolster public interest and curiosity in the universe as no other type of telescope can. Whether perched in the weightlessness of space or standing in a 4.5-billion-year-old lunar crater, this spidery monster of glass will be a lasting monument to our passionate curiosity. Luckily, our deep vision will not falter for too long between the exciting universe unveiled by Hubble and the unimaginably more exciting universe awaiting the VLST. A

To learn more about the James Webb Space Telescope and its capabilities, visit www.astronomy.com/toc



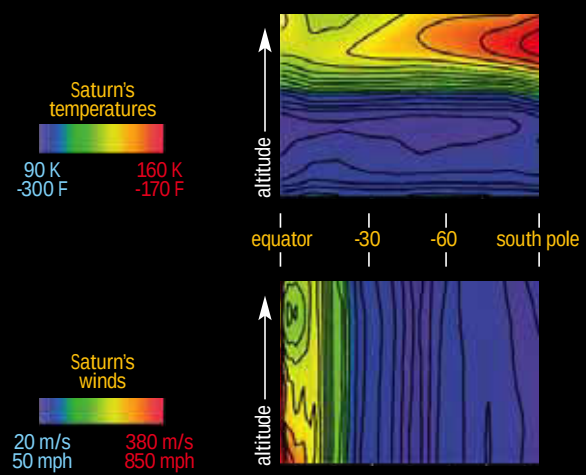
LOOMING LARGE in Cassini's camera, Saturn is both familiar and strange. The last spacecraft visit was in 1981, and Cassini's 4-year tour will remake our views of this ringed world. NASA/JPL/SSI

Cassini reaches Saturn

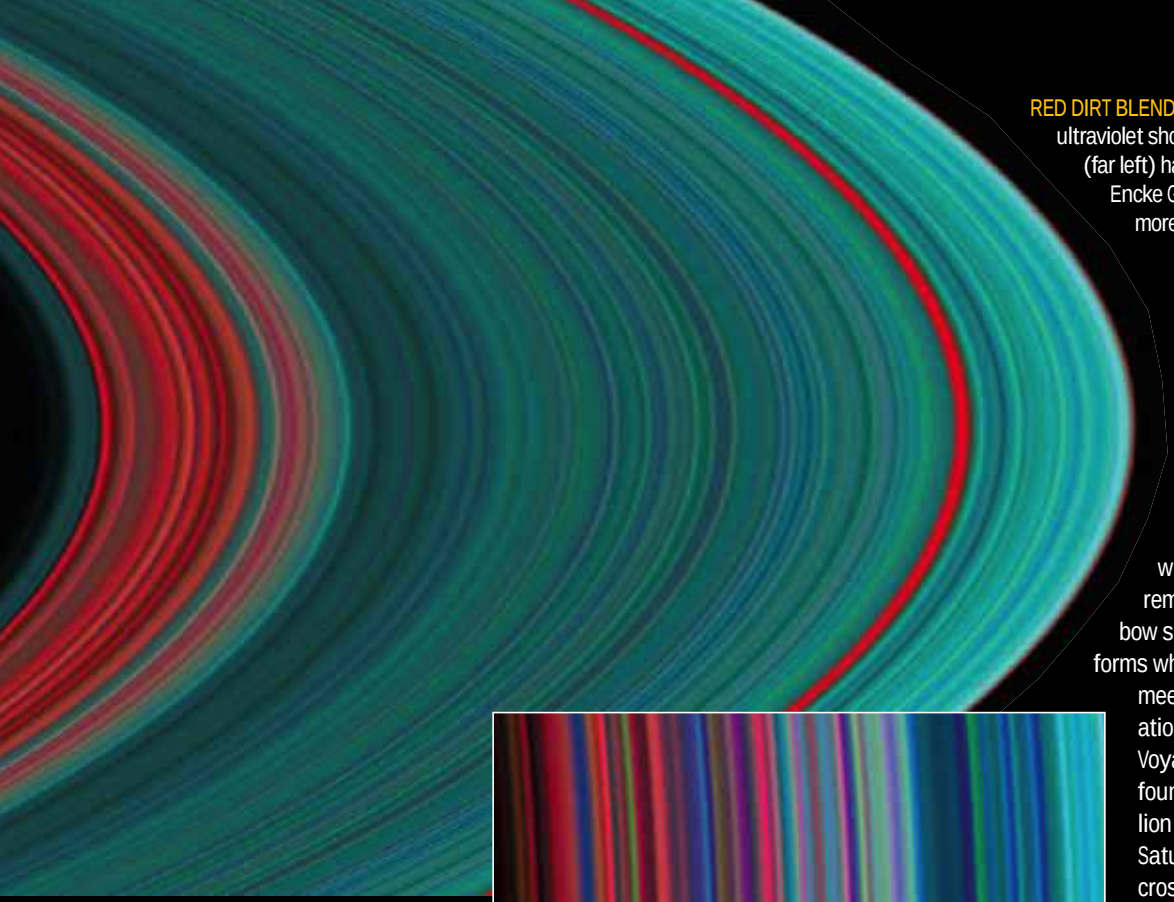
The Cassini spacecraft enters orbit around Saturn, returning the first close-up images of the planet and its moon Titan in nearly 25 years. /// BY RICHARD TALCOTT

That gust of wind you may have felt on the night of June 30 wasn't some strange new weather phenomenon. Rather, it was a collective sigh of relief emanating from NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. Hundreds of mission scientists, engineers, and planners had been holding their breath as the Cassini spacecraft executed a complex series of maneuvers that placed it into orbit around Saturn.

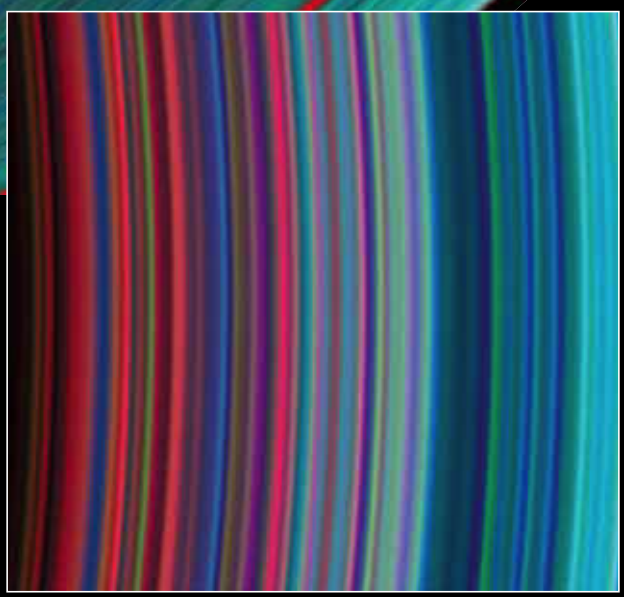
Although the spacecraft performed flawlessly, that didn't prevent anxiety among the mission's human contingent. Cassini had to pass through Saturn's ring plane twice, risking an unlikely but possible deadly collision with a sizable ring particle. Even more daunting was the 96-minute engine burn designed to slow the spacecraft enough for Saturn's gravity to capture it. If the engine (or its backup) hadn't fired at the right time — and ended just as punctually — the mission would have become the most expensive planetary flyby in history.



FORECAST: COLD AND WINDY. The Sun is shining strongly on Saturn's southern hemisphere. This raises the temperature of its upper polar atmosphere (top). By contrast, equatorial winds blow most powerfully, especially at lower depths in the planet's atmosphere (above). NASA/JPL/GSFC



RED DIRT BLENDS WITH GREEN ICE in this false-color, ultraviolet shot of the A ring. The Cassini division (far left) has lots of dirt, as does the narrow Encke Gap. The C and B rings (below) show more complex patterns. NASA/JPL/UNIV. COLORADO



Yet after a 2.2-billion-mile journey (3.5 billion kilometers), the bus-size Cassini spacecraft hit its target precisely, and the crowd at JPL broke into cheers and applause. Just after the engine burn finished, the spacecraft aimed its instrument platform toward the rings, capturing the most detailed views ever of the solar system's most scenic place. Then, after successfully negotiating the ring plane once again, Cassini took its first good look at Saturn's large moon Titan. The instruments penetrated the haze shrouding this enigmatic world, showing a landscape apparently forged more by tectonic events than impact scarring.

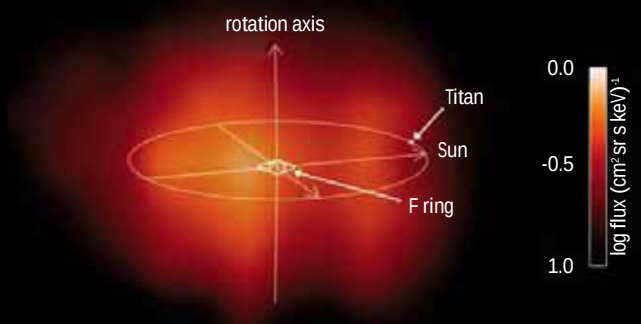
A first taste of Saturn

Cassini gave planetary scientists an early present when it flew past Saturn's small, outer moon Phoebe June 11. The spacecraft returned images of a cratered world with a dark, carbon-rich veneer and bright splashes of water ice. All in all, a textbook example of what scientists think may be typical of an object that formed in the outer solar system and later was captured by Saturn. (See "Cassini spies Phoebe," *Astronomy*, September 2004.) Yet Phoebe still holds some secrets tightly — scientists have yet to identify a "mystery component" of the dark material that covers part of the moon's surface.

The three weeks following the Phoebe encounter proved relatively uneventful, but not without surprises. A number of Cassini's instruments examined Saturn's magnetosphere. Shaped by Saturn's magnetic field, this bubble of energetic charged particles surrounds the planet and protects it from the charged particles of the solar wind. Many other planets, including Earth, also possess a magnetosphere.

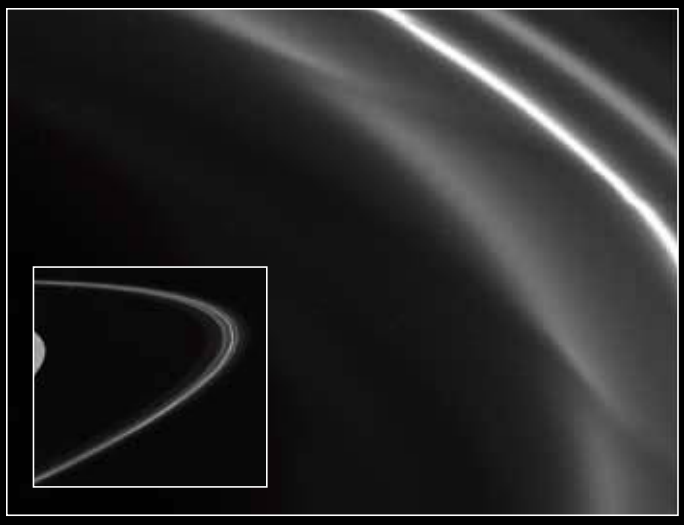
Cassini's radio and plasma wave science instrument remained on the lookout for Saturn's bow shock — the shock wave that forms where the incoming solar wind meets the magnetosphere. Observations made by the Pioneer 11, Voyager 1, and Voyager 2 spacecraft found the bow shock about 1.2 million miles (2 million km) from Saturn. But Cassini surprisingly crossed the bow shock 50 percent farther out, at a distance of 1.9 million miles (3 million km). The bow shock responds quickly to variations in how hard the solar wind blows. As Cassini approached Saturn, the spacecraft crossed the bow shock seven separate times.

The magnetosphere also came under surveillance by the magnetospheric imaging instrument, which images hydrogen atoms leaking from the magnetosphere. "With Voyager we inferred what the magnetosphere looked like, in the same way that a blind man feels an elephant," explains Tom Krimigis, the instrument's principal investigator from Johns Hopkins University's Applied Physics Laboratory. "Now we can see the elephant." The image shows the magnetosphere extends well beyond the planet's rings and perhaps beyond the orbit of Titan.

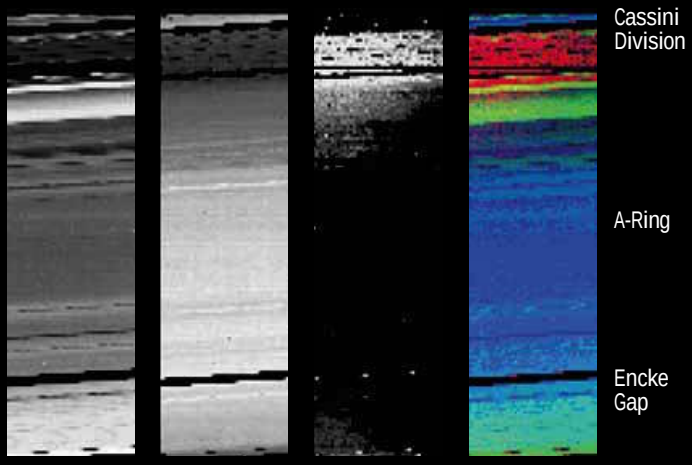


IN A SPACE-SCIENCE "FIRST," Cassini has taken an image of Saturn's magnetosphere. During the mission, Cassini will image the magnetosphere regularly, as scientists seek to tie its behavior to the wax and wane of solar activity and changes in the field of the planet itself. NASA/JPL/JHU

Richard Talcott *is a senior editor of* Astronomy.



THE RIBBON-LIKE F RING lies just outside the A ring. Confined and sculpted by the gravity of the tiny shepherd-moons, Prometheus and Pandora, the F ring displays a banded and braided appearance. The factors that shape the rings may include yet-undiscovered moonlets. NASA/JPL/SSI



SEEN BACKLIT, Saturn's rings showed different faces to Cassini's VIMS instrument. By combining the data at many wavelengths, ring scientists built the map (last frame) tracing the amount of water ice compared to a material ("dirt") resembling the surface of the moon Phoebe. NASA/JPL/UNIV. ARIZONA

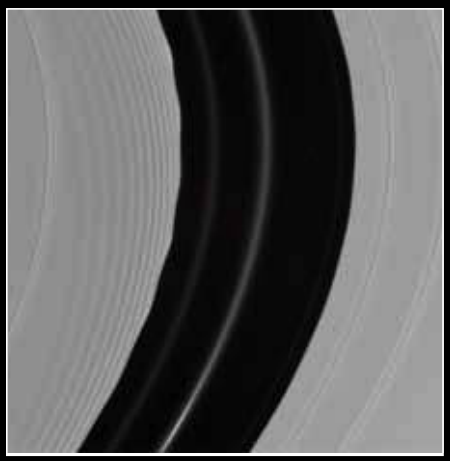
Another unexpected finding came from the ultraviolet imaging spectrograph. This instrument detected a dramatic increase in oxygen atoms coming from one side of the rings. Although detecting oxygen wasn't a surprise, the amount was staggering — some 4 times the mass of micrometer-size particles in the outermost E ring. Planetary scientists still are trying to figure this one out, although many think the oxygen excess represents the fingerprint of a recent collision — or many small collisions — within the icy rings.

A rough ride

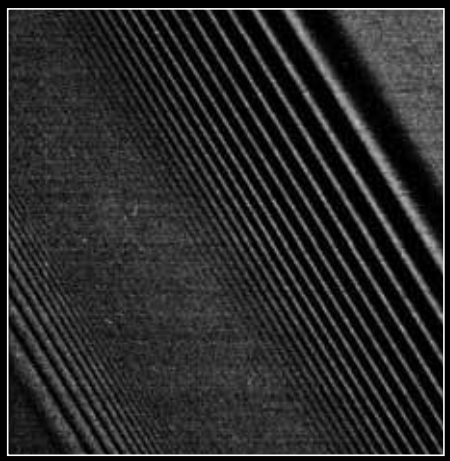
The key stages of the entire mission occurred during a 2-hour period the night of June 30. Prior to the first of two ring-plane crossings, mission planners oriented Cassini so that its high-gain dish antenna pointed straight ahead. Although the spacecraft was targeted to pass between the F and G rings, where the density of particles should be low, the sturdy materials used to build the antenna would help to protect the more delicate instruments from possible debris. And a good thing too: The radio and plasma wave science instrument detected 680 impacts per second during the first ring-plane crossing — for a total of roughly 100,000 hits. Most particles were only about 1 micrometer in diameter, but a few were 100 times that size.

Emerging unscathed from this first ring-plane crossing, Cassini executed a programmed set of instructions. The spacecraft turned to aim its engine nozzle forward, then approximately 25 minutes after crossing the ring plane, the engine lit (a backup was ready in case it didn't) and it began slowing the spacecraft. Actually, the burn kept the spacecraft from speeding up as much as it would have otherwise.

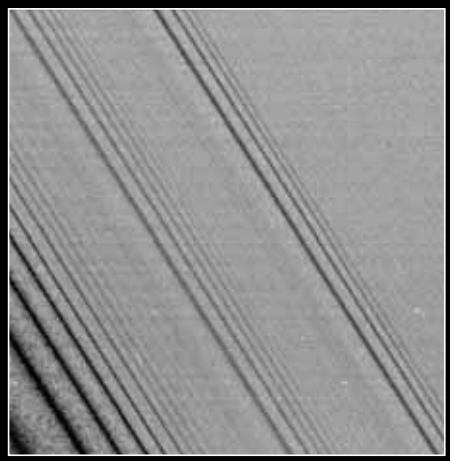
"Orbit insertion is sort of like applying the brakes while driving your car downhill," explains Cassini program manager Robert Mitchell of JPL. "Although you've got your foot on the brakes, you still pick up speed as gravity pulls you in." At the start of the burn, Cassini was traveling at 54,270 miles per hour (87,340 kph) relative to Saturn. Ninety-six minutes later, when the engine shut down, Cassini was moving at 68,293 miles per hour (109,908 kph). Still, that velocity increase represents a slowdown of 1,400 miles per hour (2,300 km per hour) compared to the speed the spacecraft would have picked up.



A SCALLOPED EDGE on the inner side (left) of the Encke Gap suggests the gravity action of the moon Pan, 16 miles across. The concentric waves inward of the edge also come from Pan's effects. NASA/JPL/SSI



TWO STYLES OF WAVES show in this image of the A ring inward from the Encke Gap. The waves on the right are density waves (clumps and voids) while at left, the ring bends up and down. NASA/JPL/SSI



THREE DENSITY WAVES weave patterns in the A ring, seen here from the rings' unlit side. By studying these patterns, scientists hope to understand the forces shaping the rings. NASA/JPL/SSI

A NATURAL-COLOR TITAN displays its photochemical smog made from organic molecules. Cassini's imager can pierce the haze, opaque to the human eye, only with a filter that uses one of the infrared bands where the moon's atmosphere is partly transparent. NASA/JPL/SSI

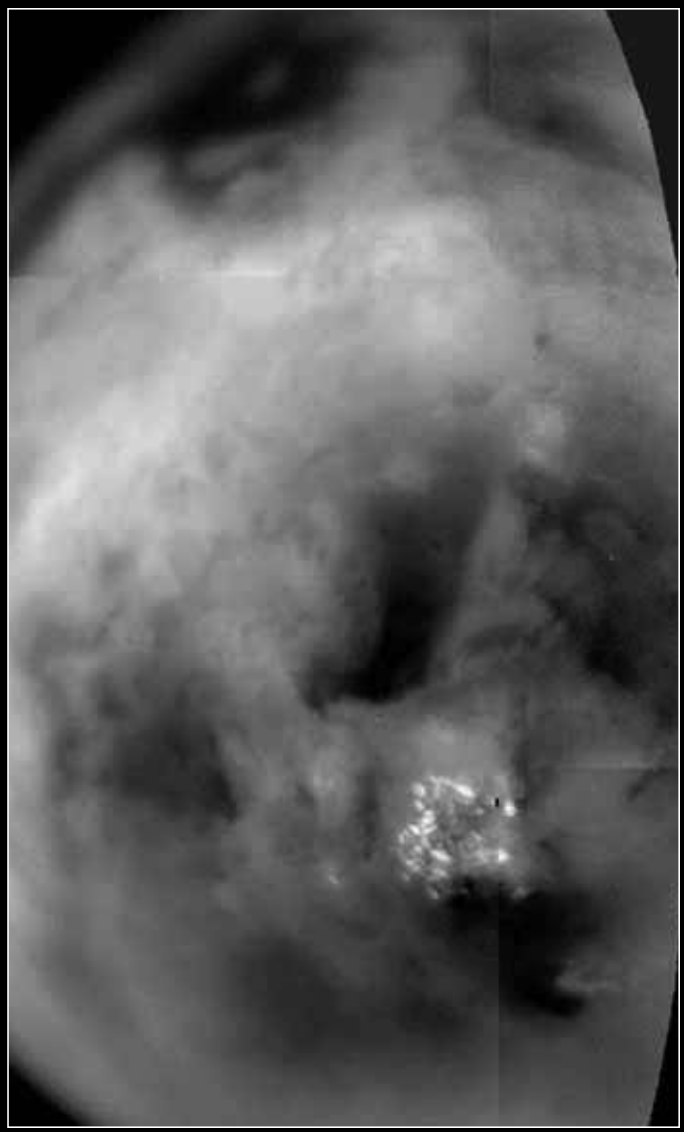
Immediately after the burn, Cassini jettisoned the cover on its ion and neutral mass spectrometer (engine exhaust would have contaminated the instrument). Then the spacecraft turned to the rings for its closest look during the whole mission. The most detailed images were taken from the dark side of the rings. (The spacecraft was above the planet's northern hemisphere while the Sun shone on the southern hemisphere.) In such backlit images, regions with a high density of particles appear black, as do areas with no particles. Regions with a low density of small particles, however, scatter light forward and thus appear bright. After Cassini passed through the ring plane the second time, the rings took on a more normal appearance, with dense regions bright and sparse ones dark.

The ring images showed a cornucopia of features: narrow and broad rings, sharp and diffuse rings, smooth and scalloped edges. "It was mind-blowing," says Carolyn Porco of the Space Science Institute, leader of the imaging team. "I'm surprised at how surprised I am." Porco emphasized that we weren't seeing individual ring particles — the best resolution was a still few hundred meters and, in any case, Cassini was moving too fast. Instead, she says, "we see a collection of particles, like a traffic jam on a highway. We see a bunch of particles together, then it clears up, then there's traffic again."

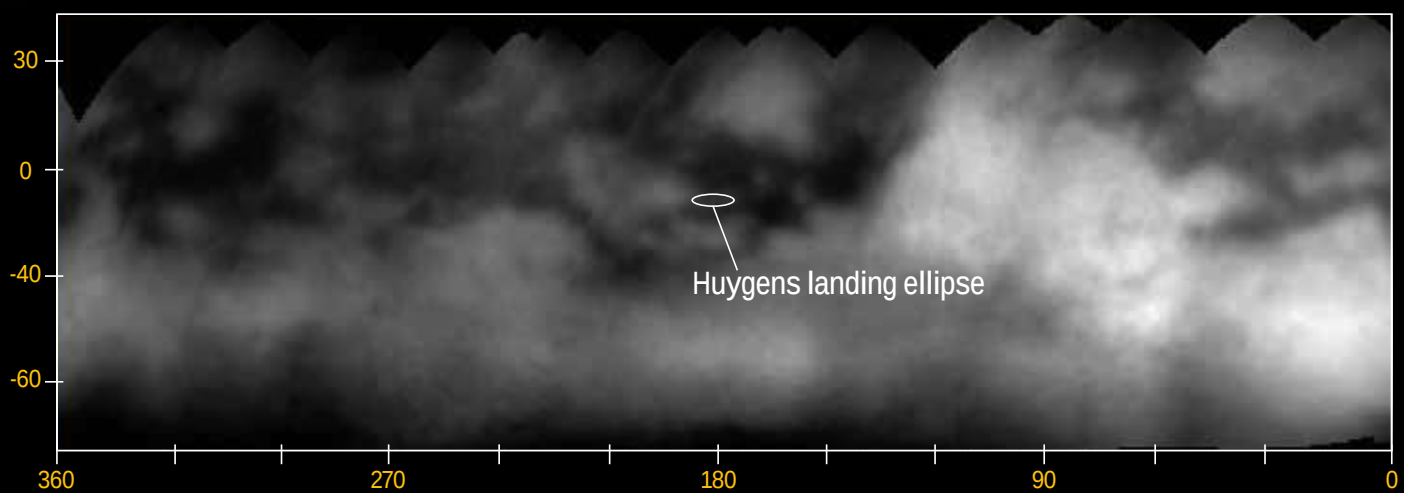
Cassini also targeted the rings with its visual and infrared mapping spectrometer (VIMS). This instrument confirmed that the rings consist of at least 90 percent water ice and showed that ring-particle size increases farther from Saturn. But most intriguing, VIMS discovered an unidentified impurity in some spots, mainly in ring gaps and in the F ring. Scientists quickly dubbed the material "dirt." The dirt has a spectral signature remarkably similar to the mysterious material previously seen on Phoebe. This suggests the rings may have formed from material coming from an outer solar system object like Phoebe.

Piercing the haze

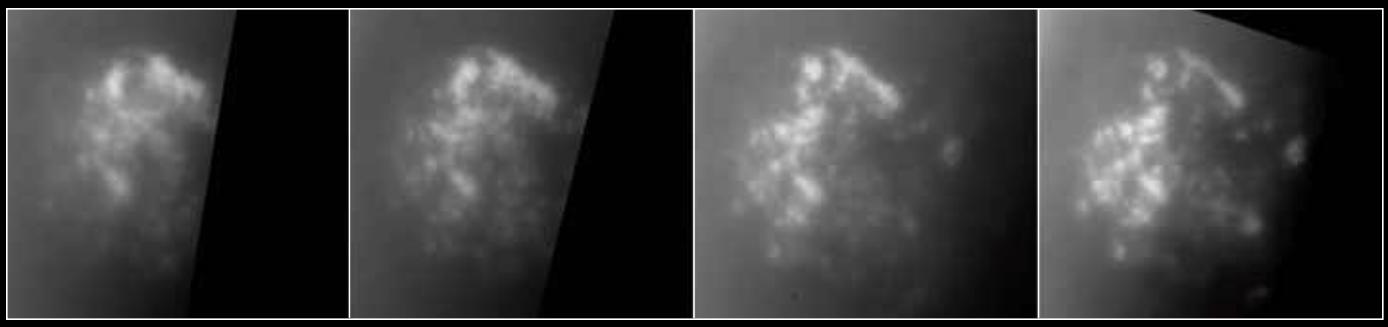
On the heels of entering Saturn orbit, Cassini cruised past planet-size Titan, the second-largest moon in the solar system. On July 2, the



SMUDGY FEATURES appear in this mosaic of Titan's south polar region. The blurry markings are surface details seen through haze. The apparent lack of large impact craters suggests internal geological activity may be important. Bright methane clouds cluster at the lower right (see opposite). NASA/JPL/SSI



MAPPING AN UNKNOWN WORLD, Cassini is sketching in the main features of Titan's smog-shrouded surface. Scientists have been struck by the relative lack of large impact craters or basins, although a hint of a circular feature shows near 150° longitude and 0° to 30° north latitude. NASA/JPL/SSI



BRIGHT CLOUDS OF METHANE CHURN near Titan's south pole in these frames taken by Cassini during a span of almost 5 hours. The smallest features visible are about 6 miles (10 km) across. This area may be active because it lies in constant sunlight during the current saturnian season. NASA/JPL/SSI

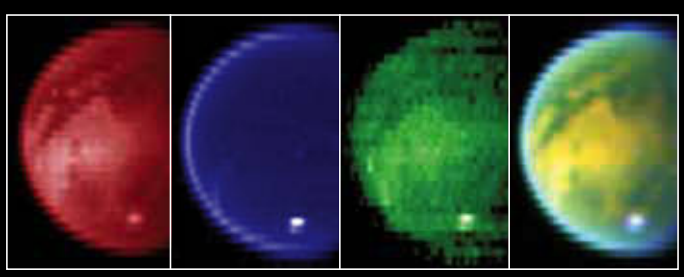
spacecraft flew within 210,600 miles (339,000 km) of this frigid, hazy world, the first of 45 Titan flybys Cassini will make during the mission. Titan has long excited scientists because it may well preserve in a deep freeze many of the chemical compounds that preceded life on Earth.

But Titan poses a problem: a thick, hazy atmosphere that until now prevented almost all views of its surface. However, Cassini's camera and VIMS instrument carry scores of filters designed to penetrate the haze. And they did.

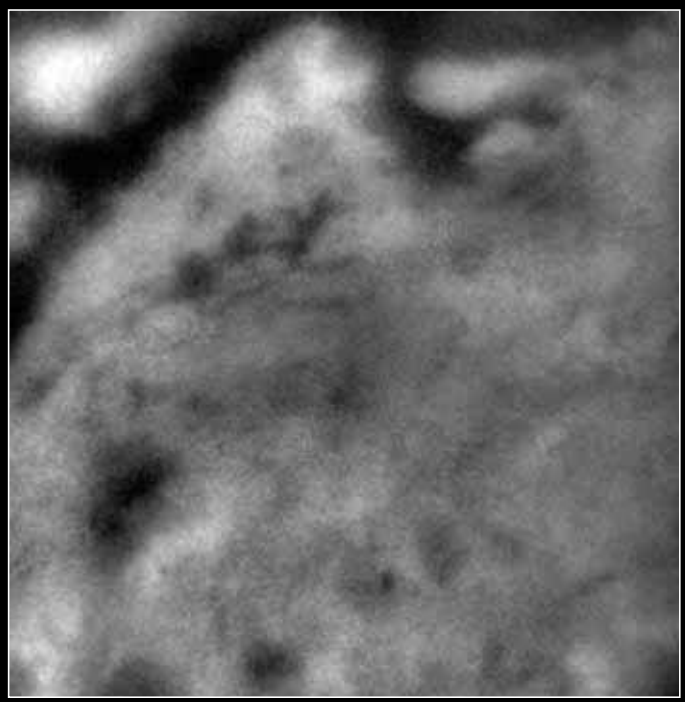
"We're seeing a totally alien surface," says imaging team member Elizabeth Turtle of the University of Arizona. "There are linear features, circular features, curvilinear features. These suggest geologic activity on Titan, but we really don't know how to interpret them yet." Not yet seen are large numbers of craters, which argues for an active geology erasing their traces. In addition, the images revealed a huge complex of methane clouds near the moon's south pole. The entire field of clouds covers some 280 miles (450 km) and shows changes over the course of a few hours. These could be cumulus-like clouds rising in the (relative) heat of Titan's day — its south polar region currently receives non-stop sunlight.

VIMS also pierced Titan's haze, revealing a world nearly opposite of what scientists expected. "At some wavelengths, we see dark regions of relatively pure water ice and brighter regions with a much higher amount of non-ice materials, such as simple hydrocarbons," says VIMS team member Kevin Baines of JPL. "Although it's preliminary, this may change the way we interpret light and dark areas on Titan."

The bright regions appear about twice as bright as the ice-rich darker regions. (The methane clouds are 10 times brighter still.) Some scientists had speculated that the darker regions might be lakes of liquid methane, but early results suggest a more complicated picture. Scientists saw no bright reflections coming from the surface. Methane lakes on Titan should act like bodies of water on Earth, glinting when sunlight hits them just right — but an ethane haze over them could hide the reflection. Radar studies from Earth do show that Titan's surface is "glinty" at scales of tens of feet.



MULTI-WAVELENGTH VIEWS map Titan. The red view (at 2.0 microns) shows dark regions that may be pure water ice. The blue image (2.8 microns) reveals a water-ice surface and simple hydrocarbons. The green image (5.0 microns) resembles the first view. At right all three are combined. NASA/JPL/UNIV. ARIZONA



CASSINI'S SHARPEST LOOK SO FAR shows features on Titan that are due entirely to surface brightness, not topographic relief. The smallest details seen here are 6 miles (10 km) across. Closer flybys will soon show more. NASA/JPL/SSI

Of course, a flyby distance of more than 200,000 miles doesn't yield the sharpest views. After its first, elongated orbit of Saturn, Cassini will zoom past Titan again October 26 at a distance of just 750 miles (1,200 km). The imaging team plans to photograph much of one hemisphere of Titan during this flyby, and VIMS will start to map the surface composition in detail. The October flyby also marks the first chance for the RADAR experiment to survey the surface. After another close flyby December 13, Cassini returns to Titan in January 2005 for the long-awaited delivery of the Huygens probe.

Cassini now can begin its detailed study of Saturn, its rings, its moons, and its magnetosphere. As Dennis Matson, Cassini project scientist at JPL says, "The planet has lots of mysteries we know about, and probably a whole lot of mysteries we don't know about." The next 4 years should do much to solve them. A

To see a photo gallery of the latest Cassini images, visit www.astronomy.com/toc

{ STELLAR ASTRONOMY }

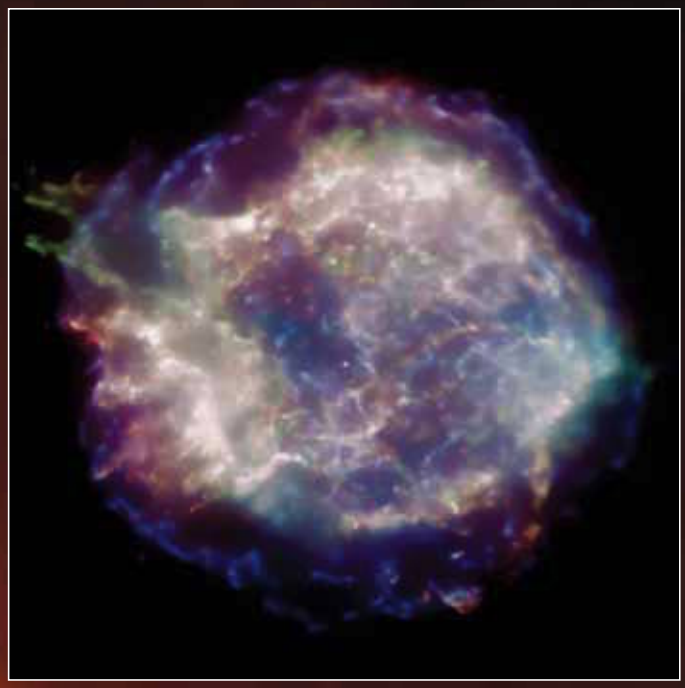
The star-splitting JETS of supernovae

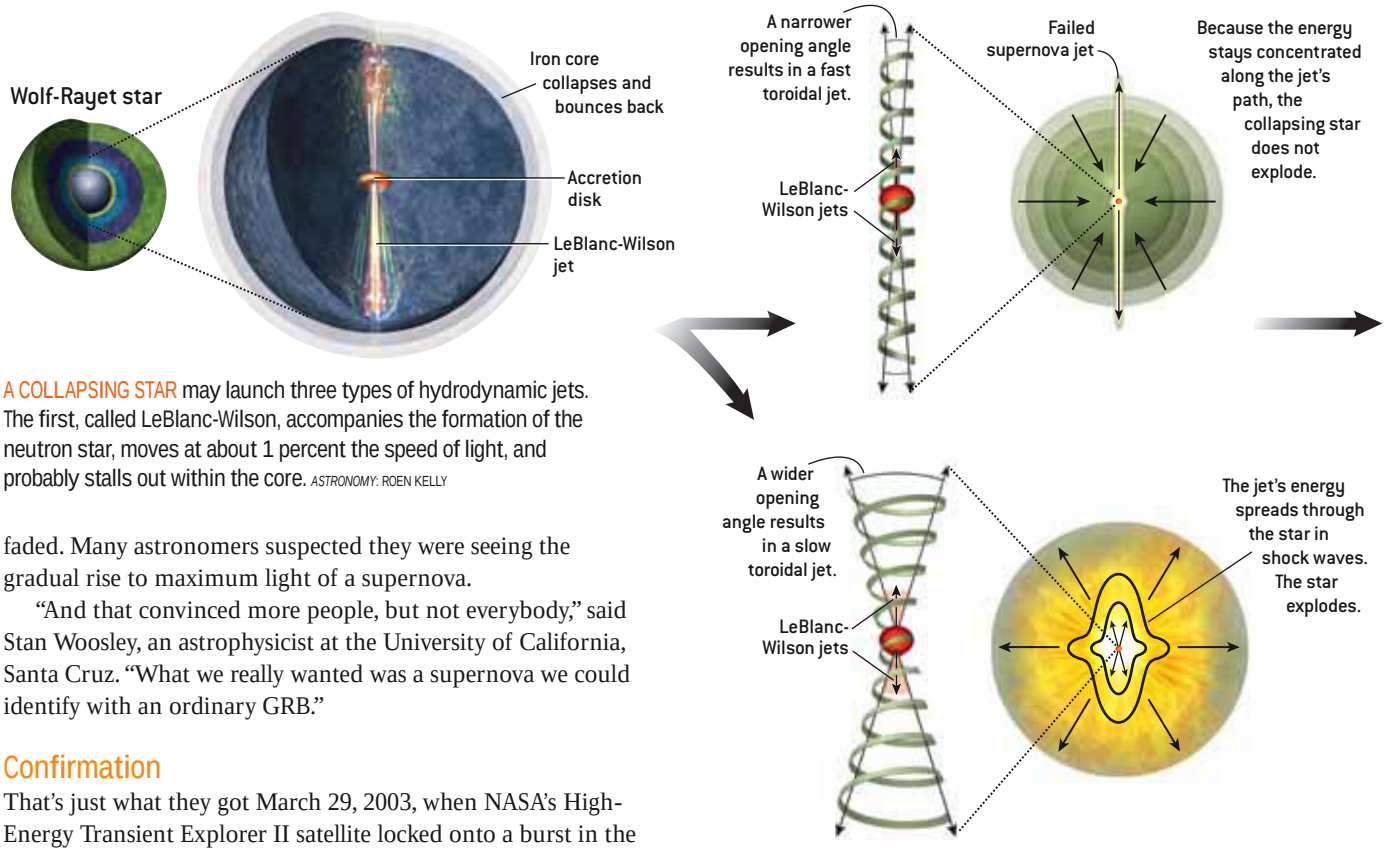
To explain the existence of unusually energetic supernovae and gamma-ray bursts, astrophysicists invoke jets of matter moving at nearly the speed of light. /// BY FRANCIS REDDY

Recent discoveries confirm a long-suspected link between two of the most energetic phenomena in the universe: exploding stars, called supernovae, and long-duration gamma-ray bursts — those lasting more than two seconds. Gamma-ray bursts (GRBs) occur at a rate of about one per day and were first recognized in the 1970s. But the first compelling evidence linking them to stellar explosions came April 25, 1998, when astronomers found an unusually powerful supernova, designated SN 1998bw, at the position of a long-duration burst. That event, called GRB 980425, didn't clinch the connection, however, because the burst was strangely weak, only $1/10{,}000$ as energetic as other long bursts for which distances were known.

Circumstantial evidence mounted in the following years. GRBs seemed to be associated with areas of active star formation, which was consistent with the short lives of massive stars thought to be supernova candidates. Transient patches of light found at some GRB positions — called optical afterglows — sometimes exhibited "bumps" in brightness after a few days; occasionally, hints of supernova-like features emerged as the afterglow

JETS BLASTING FROM THE CENTER OF A COLLAPSING STAR give rise to gamma-ray bursts. Earlier, less energetic jets may help explode supernovae. *Inset*, CASSIOPEIA A is a young supernova remnant located about 10,000 light-years from Earth. A jet is apparent at about the ten o'clock position, and a hint of a hole in the shell — the counter jet — can be seen at about four o'clock. MARK GARLICK; NASA/CXC/SAO




Phase 1: Formation of LeBlanc-Wilson jets
Phase 2: Formation of toroidal jets
Wolf-Rayet star
Iron core collapses and bounces back
Accretion disk
LeBlanc-Wilson jet
A narrower opening angle results in a fast toroidal jet.
LeBlanc-Wilson jets
Failed supernova jet
Because the energy stays concentrated along the jet's path, the collapsing star does not explode.
A wider opening angle results in a slow toroidal jet.
LeBlanc-Wilson jets
The jet's energy spreads through the star in shock waves. The star explodes.

A COLLAPSING STAR may launch three types of hydrodynamic jets. The first, called LeBlanc-Wilson, accompanies the formation of the neutron star, moves at about 1 percent the speed of light, and probably stalls out within the core. *ASTRONOMY:* ROEN KELLY

RAPID ROTATION AND INTENSE MAGNETIC FIELDS may launch a faster, helix-shaped, toroidal jet. Moving at perhaps 10 percent the speed of light, this jet may survive long enough to deposit its energy in the outer layers of the star and could even escape it.

faded. Many astronomers suspected they were seeing the gradual rise to maximum light of a supernova.

"And that convinced more people, but not everybody," said Stan Woosley, an astrophysicist at the University of California, Santa Cruz. "What we really wanted was a supernova we could identify with an ordinary GRB."

Confirmation

That's just what they got March 29, 2003, when NASA's High-Energy Transient Explorer II satellite locked onto a burst in the constellation Leo. For 25 seconds GRB 030329 outshone everything in the universe at gamma-ray wavelengths. Ninety minutes later, astronomers at Siding Spring Observatory in Australia found its afterglow, still more than a trillion times brighter than the Sun. Within a day a detailed spectrum obtained at Paranal Observatory in Chile showed that the burst was located 2.65 billion light-years away, making it the second-nearest long-duration GRB ever detected. (GRB 980425, which was 140 million light-years away, remains the closest.) The proximity of GRB 030329 resulted in very bright afterglow emission, permitting the most extensive follow-up observations to date. On April 7, a team led by Thomas Matheson of the Harvard-Smithsonian Center for Astrophysics announced that spectral lines characteristic of a supernova were emerging from the burst's afterglow. The observation was quickly confirmed and the supernova was given its own designation: SN 2003dh.

Some called the event a watershed for high-energy astrophysics and likened it to a cosmic Rosetta Stone. "I think today it is absolutely certain that some subset of gamma-ray bursts are made when massive stars die and that the bursts are accompanied by supernova explosions," Woosley said.

Astronomers immediately were struck by similarities between SN 2003dh and SN 1998bw. Both were classified as Type Ic supernovae — massive, particularly energetic stars expanding at more than twice the speed of ordinary supernovae. The expansion of SN 2003dh was measured at 22,000 miles per second (36,000 kilometers per second), the fastest of any observed supernova. Such energetic events once were called "hypernovae," but many consider this term poorly defined and no longer use it.

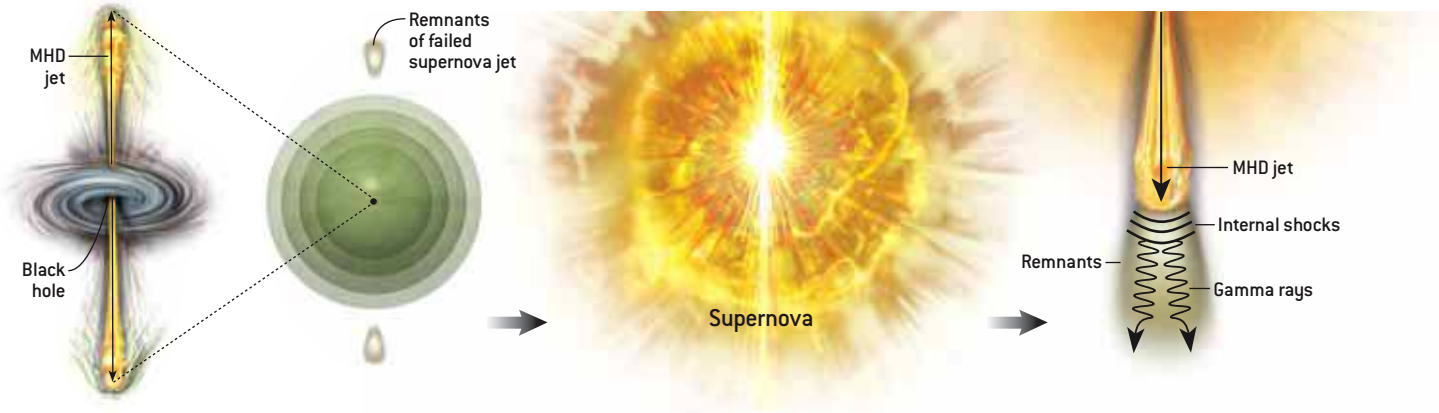
What was it?

The best fit with our understanding of GRBs is the "collapsar" model introduced by Woosley in 1993, which predicted an observational link between long GRBs and supernovae. Three essential components must be present: a particular type of massive star, called a Wolf-Rayet star; a rotating stellar core; and a core collapse that failed to produce a successful supernova, resulting in a black hole at the center of the star.

Wolf-Rayet stars begin their lives with masses more than 20 times that of the Sun. They lose about two-thirds of that mass during their short hot lives, either by vigorous stellar winds or through interactions with a nearby companion star. A typical star in Woosley's calculations begins life with between 30–35 solar masses. After 5 or 6 million years, its hydrogen envelope has been removed, and its mass has dropped to perhaps ten or twelve suns. On the inside, the star has taken on the layered structure characteristic of advanced stellar evolution. The star supports itself against collapse by running through a succession of nuclear fuels culminating with a core filled with iron-group elements. At that point, the process can no longer continue. The star's surface now lies far out in the extended atmosphere formed by its strong stellar

Francis Reddy *is an associate editor at* Astronomy.

Phase 3: Core-collapse supernova and gamma-ray burst



A THIRD JET — called a magnetohydrodynamic (MHD) jet — may form if the neutron star is highly magnetized and rapidly rotating, or if a black hole with an accretion disk forms (as in the collapsar model).

THIS JET MOVES AT NEARLY THE SPEED OF LIGHT and interacts with material ejected by slower jets. According to one theory, internal shocks from this collision create a gamma-ray burst.

wind and is several times larger than our Sun. From the outside, observers would see a star with a spectrum rich in helium, carbon, and oxygen, a stellar wind of 900 miles (1,500 km) per second or faster, and a surface temperature around 50,000 K.

When the core of the star collapses, it fails to trigger a shockwave capable of blowing the star apart. Within a second, a black hole of between 3–4 solar masses forms. The collapse dramatically magnifies the rotation speed of the star. This increases the centrifugal force and slows the infall of matter along the star's equator. This matter then piles up into an accretion disk around the black hole. But nothing resists the collapse along the star's spin axis and, during the next few seconds, matter raining down toward the black hole evacuates a path through the star. "There's a density contrast of at least a thousand between the poles and the equator now," Woosley said.

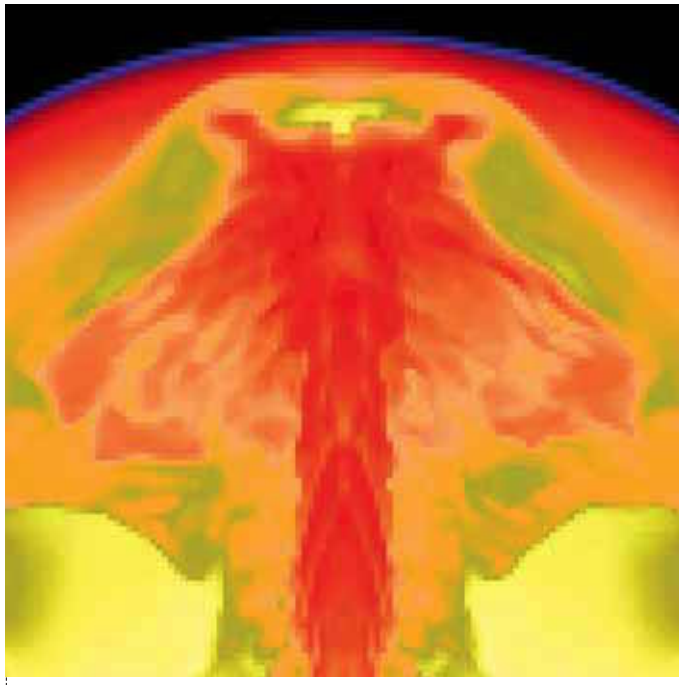
A powerful magnetic field quickly arises from the dynamo created by the spin of the black hole and the differential rotation of its accretion disk. This field accelerates matter outward along the path of least resistance. A small amount of stellar material blasts out along the star's spin axis moving at 99.5 percent the speed of light. When this jet breeches the star's surface between 6 and 8 seconds later, it expands outward and accelerates to 99.999 percent the speed of light. "No bulk matter moves faster in the universe except the nuclei in cosmic rays," Woosley said.

The core of the jet has a very small mass, only about a hundred-thousandth that of the Sun, but it has tremendous internal energy. When the jet breaks out of the star, blobs of its fastest-moving matter interact with one another and emit the gamma rays we detect as a GRB. Both theory and observation suggest that the emerging jet typically has a radius of about 5°, so we see a GRB only when a jet happens to be directed toward Earth. Woosley estimates that for each burst astronomers observe some 300 remain undetected.

The jet continues outward and interacts with the star's extended atmosphere, energizing the gas so that it gives off radio waves, light, and X rays — radiation we observe as afterglow emission. Meanwhile, an asymmetric supernova has begun. Portions of the star neither ejected in the jet nor captured in the black hole expand rapidly along the rotational axis and more slowly along the equatorial plane.

"As recently as 5 years ago there were more than 100 models for gamma-ray bursts. Now it's narrowed down to two," Woosley said. Do GRBs always require a black hole or can an exceptional, highly magnetized, rapidly rotating neutron star also do the job? "This is the level at which we now argue," he said.

"My personal bet is that the GRBs do represent black hole formation," Wheeler stated. He argues there exists no direct



A SUPERNOVA JET breeches the surface of a collapsing Wolf-Rayet star at nearly the speed of light. Brighter colors indicate higher densities. When the jet exits the star, gamma rays produced in its fastest-moving material create a GRB, which will be visible if the jet points toward Earth. WEIQUN ZHANG, STAN WOOSLEY (UCLA, SANTA CRUZ) AND ALEXANDER HEGER (LOS ALAMOS NATIONAL LABORATORY)

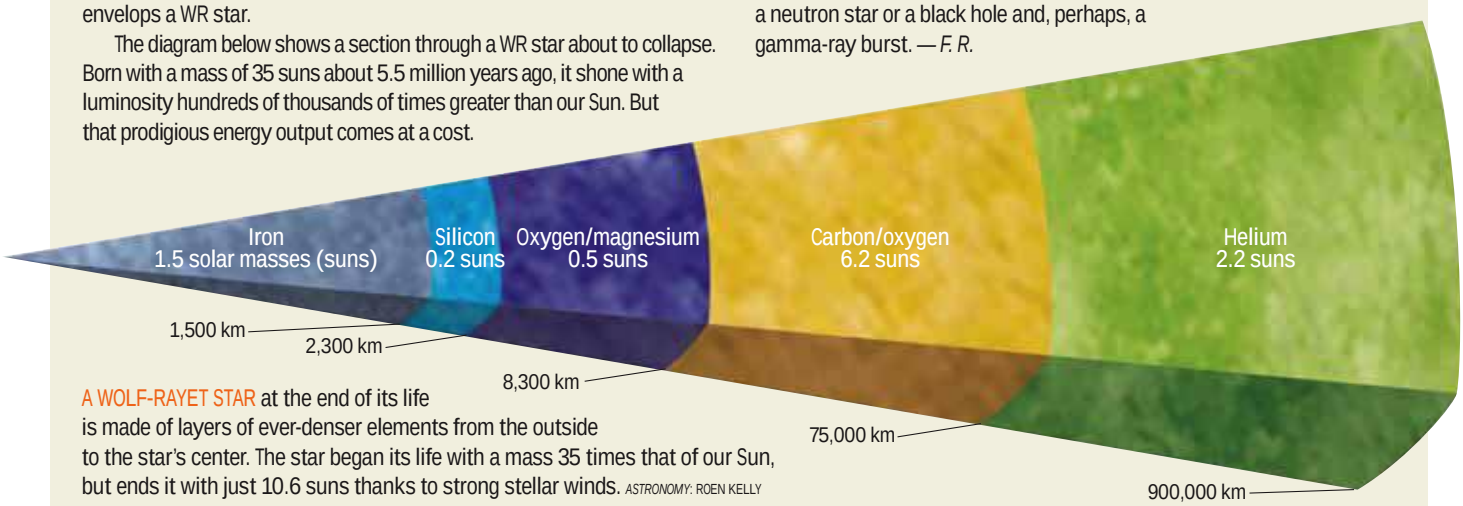
/// BEFORE THE FALL: INSIDE A WOLF-RAYET STAR

The collapsar model for gamma-ray bursts requires a specific type of star known as a Wolf-Rayet (WR) star. French astronomers Charles Wolf and Georges Rayet first identified this type of star in 1867. Wolf-Rayets are extremely rare — only 226 have been identified in our galaxy.

WR stars have masses at least 20 times that of the Sun and surface temperatures between 30,000 K and 60,000 K. Violent stellar winds of more than 900 miles (1,500 km) per second quickly bleed off the star's outer layers. WR stars may lose more than two-thirds of their mass during their lifetimes. The expulsion of so much gas means that an "atmosphere" larger than the star, whose actual surface is hidden, envelops a WR star.

The diagram below shows a section through a WR star about to collapse. Born with a mass of 35 suns about 5.5 million years ago, it shone with a luminosity hundreds of thousands of times greater than our Sun. But that prodigious energy output comes at a cost.

The star rapidly depleted the hydrogen fuel supply in its core and collapsed, producing energy by fusing helium, the by-product of hydrogen fusion. Meanwhile, vigorous stellar winds blew away more than two-thirds of the star's original mass. After a few hundred thousand years, the star needed a new source of fuel, this time carbon. The process of fusing heavier elements is one of rapidly diminishing returns. It took only months to require a new fuel — oxygen, then neon. Finally, silicon will begin to fuse, filling the core with iron-group elements. But that will be the end of the line — iron fusion liberates less energy than it consumes. The star will soon collapse and explode as a supernova, giving birth to a neutron star or a black hole and, perhaps, a gamma-ray burst. — *F. R.*



A WOLF-RAYET STAR at the end of its life is made of layers of ever-denser elements from the outside to the star's center. The star began its life with a mass 35 times that of our Sun, but ends it with just 10.6 suns thanks to strong stellar winds. *ASTRONOMY:* ROEN KELLY

observational evidence for black hole formation, only that large energies, velocities near the speed of light, and directional flow of jet material are involved.

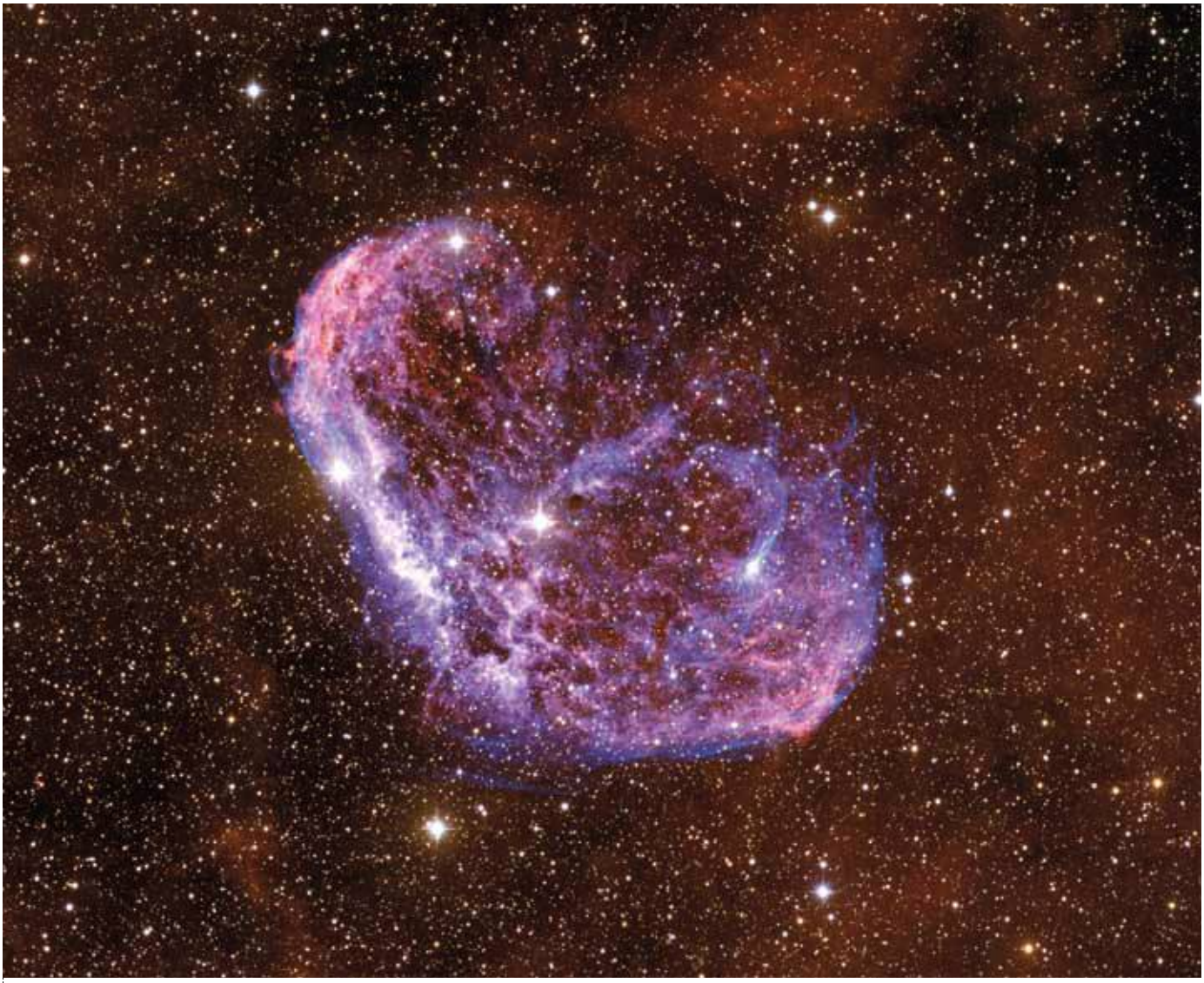
Wheeler notes that our knowledge of how a collapsing stellar core turns into an expanding supernova is preliminary at best. He says new evidence — and a fresh look at old evidence — suggests that lower-energy jets may play an important role in many, if not most, supernovae. For example, detailed optical studies of the supernova remnant known as Cassiopeia A revealed a multi-jet structure, part of which was imaged by the Chandra X-ray Observatory in 1999. In addition, elongated ejecta have been found in the remnant of SN 1987a, the first supernova visible to the unaided eye in 400 years.

Moving right along

Another line of evidence for asymmetrical supernovae is the curiously high space velocities of pulsars and neutron stars. The Crab and Vela pulsars move at about 60 miles (100 km) per second, a speed that might be explained by the breakup of a binary star system and the subsequent "slingshot" of the pulsars. But the point source in Cassiopeia A is moving at 200 miles (330 km) per second and it's thought that perhaps as much as 15 percent of the neutron star population is moving several times faster than this. One possibility is that a small fraction of the energy of an asymmetric supernova provides a "kick" to the newborn neutron star. X-ray studies of the compact nebulae around the Crab and Vela pulsars reveal two-sided, asymmetric jets at positions that correspond to their lines of motion across the sky. Moreover, the observed jets also appear to be aligned with the rotation axis of each pulsar. Are these vestiges of more powerful jets that accompanied the birth of the neutron stars?

New evidence for asymmetry comes from polarization studies of numerous supernovae by Lifan Wang, now at Lawrence Berkeley National Laboratory. Polarization of light occurs when light is scattered and oriented in a certain direction. When light scatters through the layers of the expanding shell of a supernova, it retains information about how it was scattered. If a supernova is spherically symmetric, all orientations of scattered light will be present equally and the light will carry no net polarization. Wang found the light from more than a dozen supernovae to be polarized, which implies that asymmetry is an inherent part of the supernova process. Not surprisingly, supernovae of type Ib/c tend to be the most highly polarized. The growing body of polarization evidence, Wheeler said, means "It's not that Cas A and '87A are a couple of weird oddballs, but that every single core-collapse explosion is asymmetric, without exception so far — so that's a new observational fact on the ground."

The standard model for turning a core collapse into a supernova involves the emission of neutrinos after the core has compressed to nuclear density and rebounded, or "bounced," creating a neutron star. The total energy available in neutrinos is 300 times the energy of an ordinary supernova. And although less than 1 percent deposit their energy in the neutron star's dense atmosphere, the energy causes that layer to expand and convect. Woosley explained that astronomers think neutrinos blow up the supernova, but the computer models are not consistent. Sometimes they produce explosions and sometimes they don't. In the few computer models that include rotation, a bipolar pattern naturally



THE CRESCENT NEBULA (NGC 6888) in Cygnus is a shell of gas energized by WR 136, a Wolf-Rayet star at the center of the nebula. The star loses the equivalent of our Sun's mass every 50,000 years thanks to a brisk stellar wind currently clocked at 1,100 miles (1,750 km) per second. The wind has swept up and broken through a shell of slower-moving material ejected during the star's earlier red supergiant phase. T. A. RECTOR (NRAO/AUI/NSF)

emerges at the core. It remains to be seen if this can account for the shapes of real supernovae as determined by polarimetry.

"The fact that we now know they're asymmetric — it's not a speculation, it's observational fact — and that the neutrinos alone haven't really done the job, invites me to think that whatever's making it asymmetric is also a new piece of physics," Wheeler said. "But I can't prove that yet. That's a long way down the pike." Computer simulations of core collapse are only beginning to include rotation, let alone magnetic fields. Wheeler argues that both are crucial to understanding core collapse and cites the discovery of magnetars — neutron stars with magnetic fields a thousand times stronger than that of the Crab pulsar — as evidence.

He sees an opportunity for a collapsing star to make magnetic jets in the initial collapse phase when the neutron star is forming.

"Once you've got the neutron star formed, then it's going to be causing differential rotation," said Wheeler. That's prime territory for what Wheeler calls the magnetorotational instability, which builds up a magnetic field "like gangbusters" in the milliseconds following the core bounce. This creates what Wheeler calls the "toroidal jet," which moves out at about 10 percent the speed of light and has the potential to burrow all the way through the star. "If enough of its energy is trapped in the star, it could blow the whole star up," Wheeler said. "If it turns out to be a narrow jet that punches out like a needle through a loaf of bread, then you would not blow the star up or blow it up only weakly." In that case, the collapse continues, the neutron star becomes a black hole, and a third, high-velocity jet may form — a physical situation similar to that required for Stan Woosley's collapsar.

"We've got the bipolarity. We've got the asymmetry. We've got the fact that if it's rotating fast enough it will be magnetic, and we have a reservoir of energy. We also think a jet can blow up a star," Wheeler said. But there remains the big step of turning rotation and magnetic fields into a jet. "It's not a slam-dunk. It smells right to me," he quipped, "but, you know, things have smelled right to me before in my career." A

To learn about supernova jets, gamma-ray bursts, and more, visit www.astronomy.com/toc

BY MARTIN RATCLIFFE AND ALISTER LING

OCTOBER 04

All the bright planets now have migrated to the morning sky, but evening observers can follow asteroids, comets, and variable stars — and watch Earth's shadow creep across the Moon's visage.

The Full Moon turns copper

A nearly perfect total eclipse of the Moon

graces the sky above North and South America as well as Europe the evening of October 27. The Moon moves slowly through Earth's shadow, changing its clothing from a dazzling white to a deep orange veil and back again. A dark bite first appears at 9:14 p.m. EDT and grows to swallow our celestial neighbor completely for 80 minutes beginning at 10:23 p.m. This will be the last total lunar eclipse visible anywhere in the world until March 2007, so it's worth traveling a bit to avoid clouds.

The southern half of the Moon will be darker because it passes closest to the center of Earth's shadow. With the naked eye, some observers might be reminded of a giant, telescopic view of Mars: a bright polar cap with patchy, darker markings on the disk. Although the eclipse looks grand even from the city, it appears more impressive in a dark country sky. As the moonlight fades, the late summer Milky Way blossoms into prominence.

When the Sun, Earth, and Moon line up for a lunar eclipse, an accompanying eclipse of the Sun typically takes place 2 weeks before or after. As if receiving a consolation prize for missing lunar totality, observers with clear skies in Japan, northeastern Asia, Alaska, and Hawaii will witness a partial solar eclipse on October 13/14.

A RUDDY HUE will bathe the Moon during a total lunar eclipse October 27. The southern half of the Moon dips deeper into Earth's shadow and should appear darker. JARI PIIKKI

This past spring, the evening sky held a monopoly on bright planets and comets. Now, the best planetary displays occur in the morning, where Venus and Saturn hold court. By 6 a.m., Saturn lies high in the south and is perfectly placed for telescopic observation. Brilliant Venus slides past Regulus on the morning of October 3. Only half a Moon-width separates the very unequal pair (Venus gleams more than 100 times brighter than Regulus).

Unless you make an effort, it's easy to miss a lot of activity involving the minor bodies of the solar system. Thousands of asteroids and large chunks of space rock pace around the solar system, waiting for a potential life-altering collision with another body. Luckily for us, a potato-shaped rock a couple of miles across just misses Earth during the last week of September. See page 70 to follow the swift journey of asteroid 4179 Toutatis.

Comets may be small, typically a mile across or so, but they shed lots of dust as they round the Sun. These shrouds reflect enough light for backyard observers with modest telescopes to see them: This month, three comets come within range.

Like a broom crossing a dirty floor, Earth does its part to sweep up the dust particles littered by comets. Late on the night of October 20/21, Earth plows through part of the trail left by Comet Halley. Striking our upper atmosphere at a mind-boggling speed of more than 40 miles (66 km) per second, the dust dies a fiery death in a swift streak of light we call a meteor. A patient observer surveying the morning sky from the comfort of a lawn chair should be able to see 15 or 20 shooting stars per hour.

Far from city lights, you might see an odd glow in the east before dawn even begins. This faint glow comes from microscopic dust left over from ancient collisions among asteroids. Shaped like a pyramid with its base on the horizon, this is called the "zodiacal light" because it lines up along the constellations of the zodiac.

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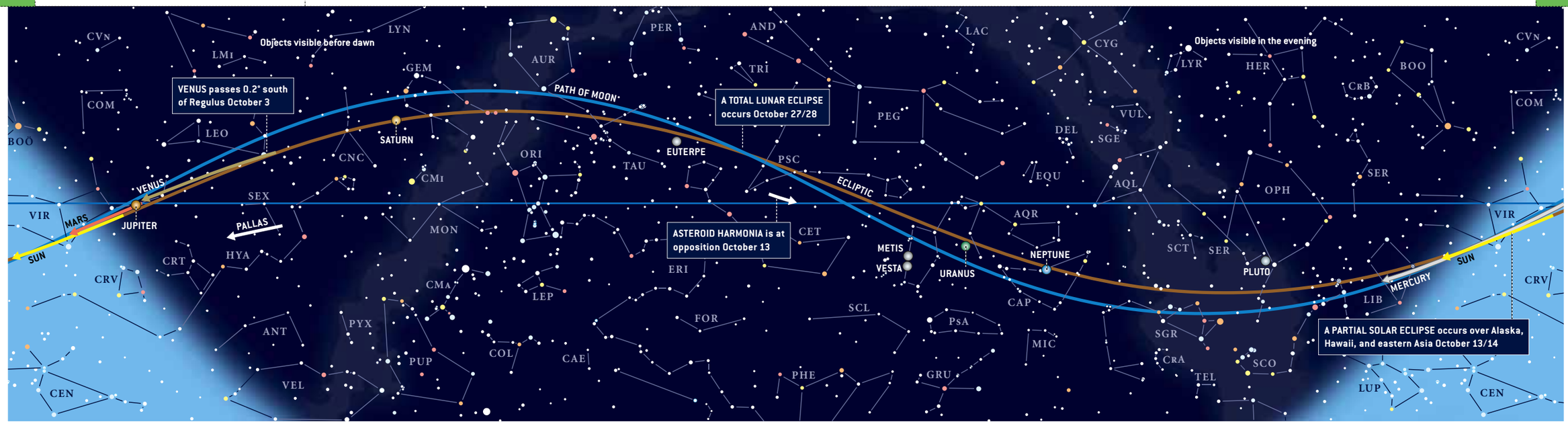
Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

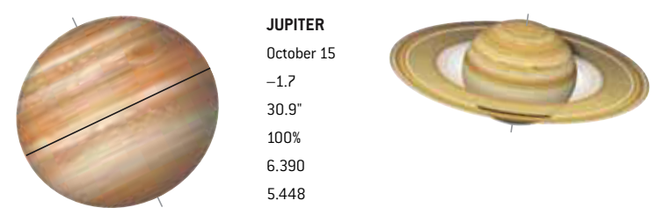


[15] [14] [13] [12] [11] [10] [09] [08] [07] [06] [05] [04] [03] [02] [01]

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

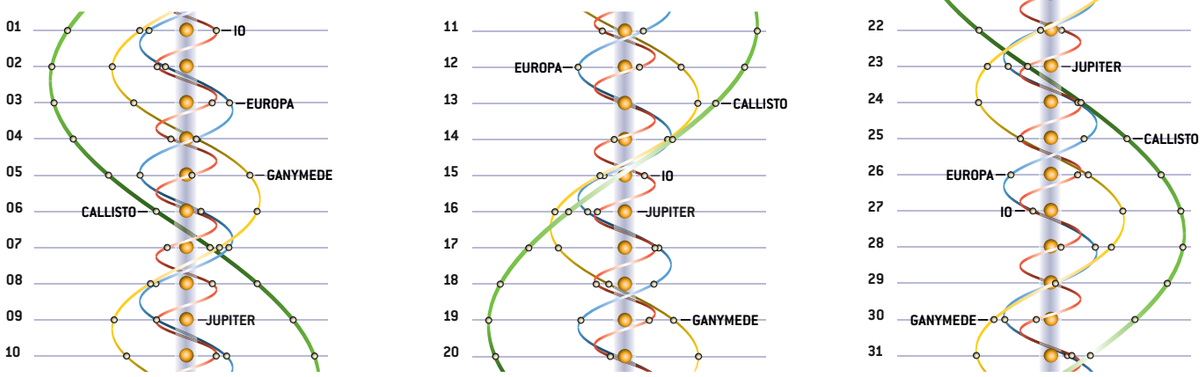
[31] [30] [29] [28] [27] [26] [25] [24] [23] [22] [21] [20] [19] [18] [17] [16] [15] [14] [13]

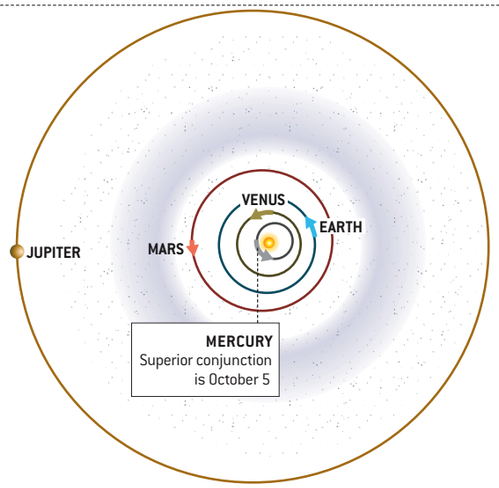
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	October 15	October 31	October 15	October 31	October 15	October 15	October 15	October 15	October 15
Magnitude	−0.9	−0.4	−4.1	1.7	−1.7	0.2	5.8	7.9	13.9
Angular Size	4.7"	5.0"	14.7"	3.6"	30.9"	18.3"	3.6"	2.3"	0.1"
Illumination	98%	91%	75%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.423	1.339	1.134	2.568	6.390	9.080	19.383	29.702	31.368
Distance (AU) from Sun	0.446	0.465	0.719	1.632	5.448	9.051	20.054	30.068	30.859
Right Ascension (2000.0)	13h45.8m	15h21.7m	10h59.4m	13h24.3m	12h17.1m	7h55.0m	22h21.4m	21h00.2m	17h19.1m
Declination (2000.0)	−10°42'	−20°05'	7°30'	−8°07'	−0°40'	20°40'	−11°06'	−17°07'	−14°48'



Jupiter's moons

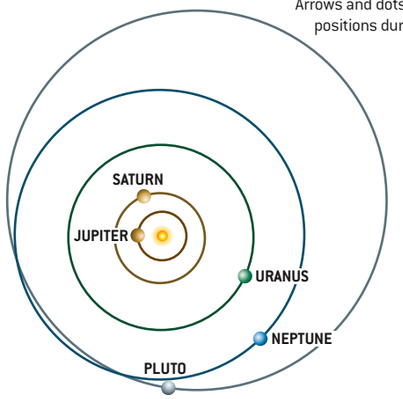
Dots display positions of Galilean satellites at 7 A.M. EDT on date shown. South is at top to match the view in a telescope.





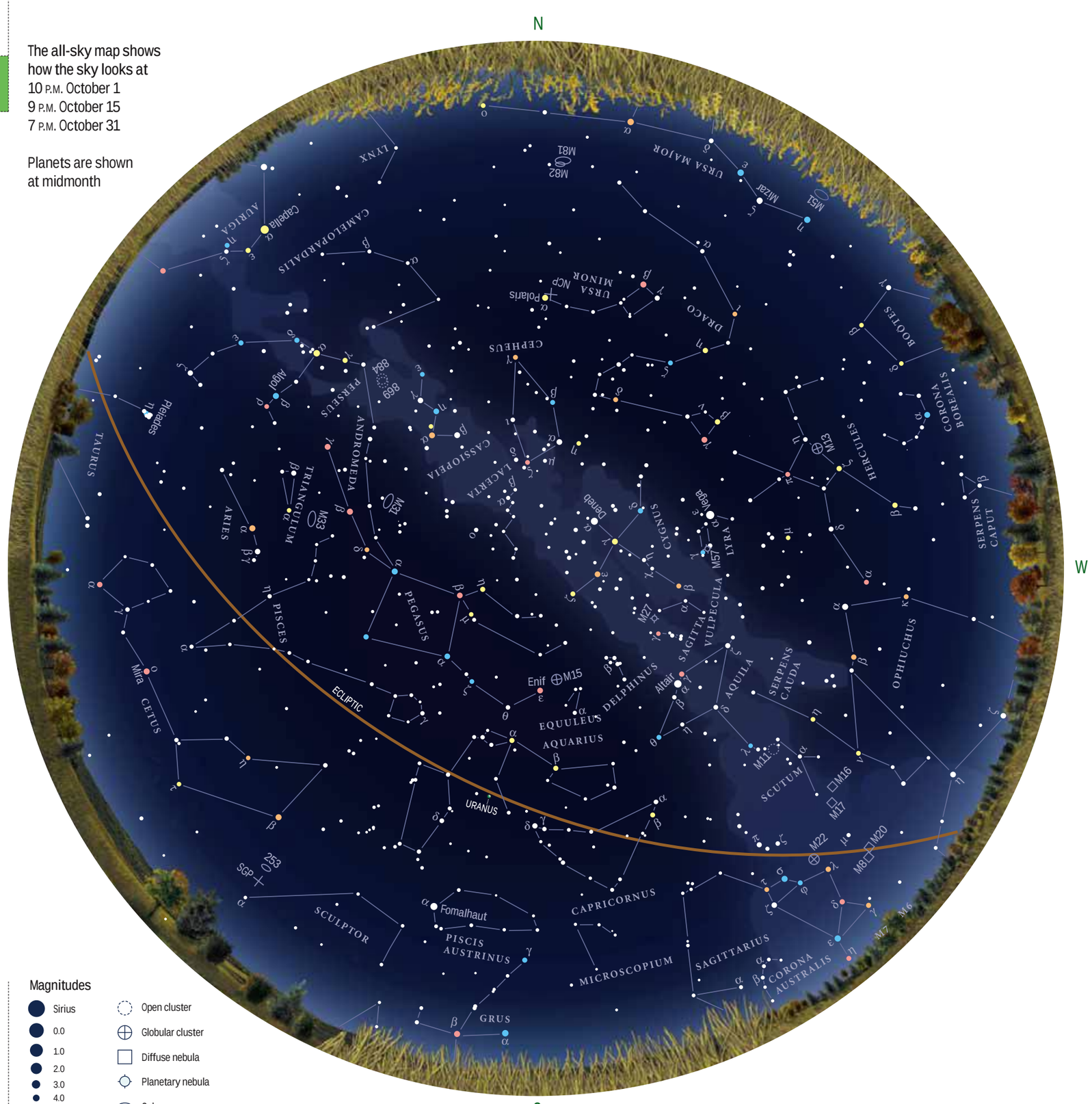
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
10 P.M. October 1
9 P.M. October 15
7 P.M. October 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

october 04

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					[01]	[02]
[03]	[04]	[05]	[06]	[07]	[08]	[09]
[10]	[11]	[12]	[13]	[14]	[15]	[16]
[17]	[18]	[19]	[20]	[21]	[22]	[23]
[24]	[25]	[26]	[27]	[28]	[29]	[30]
[31]						

03 Venus passes 0.2° south of Regulus, noon EDT

05 Mercury is in superior conjunction, 3 P.M. EDT

The Moon is at apogee (251,237 miles from Earth), 6:10 P.M. EDT

06 Last Quarter Moon is at 6:12 A.M. EDT

07 The Moon passes 5° north of Saturn, 6 A.M. EDT

10 The Moon passes 4° north of Venus, 3 P.M. EDT

12 The Moon passes 1.6° north of Jupiter, 3 P.M. EDT

13 Asteroid Harmonia is at opposition, 1 P.M. EDT

New Moon is at 10:48 P.M. EDT; partial solar eclipse

17 The Moon is at perigee (228,514 miles from Earth), 7:53 P.M. EDT

20 First Quarter Moon is at 5:59 P.M. EDT

21 Orionid meteor shower peaks

The Moon passes 5° south of Neptune, 5 P.M. EDT

23 The Moon passes 4° south of Uranus, 4 A.M. EDT

27 Full Moon is at 11:07 P.M. EDT; total lunar eclipse

31 Mars passes 3° north of Spica, 3 A.M. EST

For definitions of terms, visit www.astronomy.com/glossary

10 REASONS WHY YOU SHOULD BUY A MEADE® SCHMIDT-CASSEGRAIN:

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2. State-of-the-Art Optical System Water white glass is standard equipment in all 8", 10", 12" and 14" Schmidt-Cassegrain corrector lenses. Water white glass delivers an increase of light transmission in excess of 10% as compared to competing Schmidt-Cassegrain telescopes using green soda lime glass.
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MEADE EXCLUSIVE

8. Smart Mount™ constantly refines pointing accuracy each time an object is centered and updated. Compatible with both equatorial and altazimuth mounts.
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9. AutoStar® II controller features "Hot Keys" for quick access to a 145,000 celestial object database. AutoStar II can be updated with the latest software upgrades, guided tours and timely objects like comets free at meade.com.
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10. AutoStar Suite™/LPI™ allows even novice stargazers to capture and process stunning images of the Moon, Saturn, Jupiter... and more.
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Optical Design	Schmidt-Cassegrain					Maksutov Cassegrain
Aperture	8"	10"	12"	14"	16"	7"
Focal Ratio	f/10	f/10	f/10	f/10	f/10	f/15
Focal Length	2000mm	2500mm	3048mm	3556mm	4064mm	2670mm
Corrector Lens	water white	water white	water white	water white	BK7	BK7
Primary Mirror	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®
Price	$2,195	$2,745	$3,595	$4,995	$14,950	$2,695
UHTC (option only at time of order)	$175	$235	$295	$350	$495	$150
LPI/Autostar Suite ($149 value)	FREE	FREE	FREE	FREE	FREE	FREE
Shipping & Handling	$105	$145	$215	$265	$385	$125

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- 4-element, fully multi-coated optics
- Wide 52˚ apparent field of view (44˚ for the 40mm)
- Parfocal performance (excluding the 40mm and 56mm)
- Long eye relief, with soft eyeguards
- Great all-purpose eyepiece design

6.4, 9.7, 12.4, 15, 20, 26mm each	**$49.00** (4.54)
32, 40mm each	**$69.00** (5.26)
56mm 2"	**$99.00** (7.02)

Series 4000™ QX Wide Angle Eyepieces

New Product

- 5-element, fully multi-coated optics
- Super wide 70˚ apparent field of view
- Lens edges blackened to minimize internal reflections and improve contrast
- Superior eye relief, with soft eyeguards
- Superior contrast and pinpoint resolution
- For low- to medium-powered viewing

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20mm	**$79.00** (4.54)
26mm 2"	**$89.00** (5.26)
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World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm

- Micrometric X-Y positioning of the reticle within the field
- Excellent eye relief
- Wireless red LED illuminator with adjustable brightness control
- Multi-coated optics
- Rubber eyecup
- Bulls eye reticle
- Internal batteries included

$149.95 (6.14)

Series 4000 Plössl 9mm

- Same as above but with 6 ft. cord and plug for Meade telescopes with reticle jack

$129.95 (5.26)

AutoStar Suite™/LPI™

- **LPI (Lunar Planetary Imager)** is an easy-to-use Astrocam that delivers stunning images. Images can be stored in a variety of popular formats including FITS.
- **LPI Software** for the LPI Astrocam. Magic Eye™ focusing tool aids the user in achieving the best focus. The LPI then gathers multiple images which the software automatically stacks and aligns, producing a clear, data-rich image.
- **Image Processing** is a post-processing tool to further refine and sharpen images.
- **Planetarium Software** features over 19 million objects from which you can create AutoStar® tours. The software allows remote control of the telescope from a PC.

$149.00 (8.26)

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- 2x digital zoom
- Connect to a monitor or camcorder for surveillance
- Ergonomic compact design
- Includes tripod adapter; case; AC power supply; red, green and neutral density eyepiece filters to optimize your view

$299.00 (8.49)

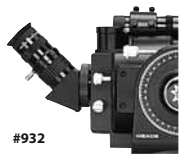
45° Erecting Prisms 1.25"

- 45° design facilitates a comfortable viewing angle for extended terrestrial viewing and spotting
- Images are fully-corrected for right-side-up and left-to-right viewing

Model **#928** for any SCT or refractor telescope focuser that accepts 1.25" O.D. accessories **$42.95** (3.86)

Model **#932** for ETX-90™, 105, and 125 model telescopes **$49.95** (3.86)

#928



#932

Barlow Lenses

Series 4000 #140 2x Barlow Lens (1.25")

- Fully color-corrected apochromatic design
- 3-element multi-coated, air spaced optics
- Double the eyepiece power
- Crisp, high contrast images

Clear aperture 26mm $79.95 (5.26)

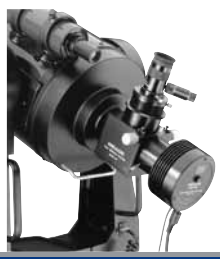
2x Short-Focus Barlow Lens (1.25")

- Double the eyepiece power
- Multi-coated optics
- Use with Meade ETX telescopes
- Insert star diagonal into it for 3x

Clear aperture 26mm $47.95 (4.54)

CCD-Photo-Visual Flip-Mirror Systems

- Flip mirrors greatly facilitate precise centering for CCD imaging
- Both #644 and #647 model Flip Mirrors incorporate a flexure-free one-piece body design, locking threaded helical focuser for the eyepiece, precision-polished UHTC-coated mirror diagonal flats, precision X/Y adjustment mechanism for the diagonal mirror with locks for precise centering, and multiple rotating adapters for T-thread and 1.25" O.D. camera attachment
- **#644 Flip Mirror System** accepts 1.25" O.D. eyepiece only and has a clear aperture of 22mm; use with small to medium size chip CCD cameras **$149.95** (7.02)
- **#647 Flip Mirror System** accepts 1.25" and 2" O.D. eyepieces and has a clear aperture of 40mm; use with medium to large size chip CCD cameras **$249.95** (8.49)



#647

#644

ETX® Hard Carrying Cases

- Convenient for storage or travel
- Hard plastic box lined with die-cut foam
- Multiple storage areas for accessories

#774 for ETX-90™ models **$99.95** (8.58)
#776 for ETX-105™ models **$99.95** (8.58)
#775 for ETX-125™ models **$149.95** (13.38)

2" Diagonal Mirrors with UHTC™

- Precision-polished flat mirror
- UHTC-coated (95%+ reflectivity)
- Includes 1.25" eyepiece adapter
- **#929** threads on to the rear cell of most SCTs **$119.95** (6.85)
- **#930** slides into any 2" focuser **$119.95** (6.85)

Series 4000 8mm-24mm Zoom Eyepiece

- 7-element, fully multi-coated optics (1.25")
- 55˚ apparent field of view at 8mm
- Internal zoom design, with graduated scale in 1mm units
- Performance is fully consistent with the finest fixed-focal length eyepieces

$219.95 (6.38)

9x63 Roof Prism Binocular

- Large 63mm aperture fully multi-coated objective lenses and BAK-4 roof prisms deliver bright images, perfect for surveying the constellations and observing nebulae and comets
- Multi-coated long eye-relief, wide apparent field eye-pieces are fitted with comfortable rubber eyecups
- The lightweight, rubber-coated body is perfectly sculpted for comfortable hand-held use

$99.00 (9.33)

Filters

Series 4000 Photo-Visual Color Filters

- Large, 26mm aperture, anti-reflection coated
- Filter is pure crown glass, dyed-in-the-mass
- Threads onto most 1.25" eyepieces
- Increases contrast of fine planetary features

Set #1: #12, #23A, #58, #80A	**$49.95** (4.54)
Set #2: #11, #25A, #47, #82A	**$49.95** (4.54)
Set #3: #8, #21, #38A, #56	**$49.95** (4.54)

** Individual filters may be purchased separately for **$14.95*** (2.73)

Series 4000 Moon Filter

- Reduces glare and irradiation during lunar observing
- 13% uniform light transmission across the visual spectrum
- Threads into 1.25" barrels

$16.95 (2.73)

#911B

Series 4000 Nebular Filters

- Premium multi-layer interference filters
- Broadband filters are great for all types of deep sky observing, and will block most forms of light pollution

#908B

#908B: Threads into 1.25" eyepieces, 26mm diameter **$79.95** (4.54)
#911B: Threads on to the rear cell of most SCTs, 36mm diameter **$99.95** (5.26)

- Narrowband filters yield spectacular high contrast views of faint nebulae, and work in heavily light-polluted conditions

#908N: Threads into 1.25" eyepieces, 26mm diameter **$89.95** (4.54)
#911N: Threads on to the rear cell of most SCTs, 36mm diameter **$119.95** (5.26)

Series 4000 Oxygen-III Filters

#911X

- Exclusive Meade 60-layer interference coating gives incredible O-III transmission performance
- Observe diffuse emission, planetary nebulae and supernova remnants
- Isolate the 496nm and 501nm O-III lines

#908X

#908X: Threads into 1.25" eyepieces, 26mm **$99.95** (4.54)
#911X: Threads on to the rear cell of most SCTs, 36mm diameter **$149.95** (5.26)

SCT Wedges for Polar Alignment

- Equatorial wedge for 8" LX90 **$169.95** (20.00)
- Standard equatorial wedge: use with Meade's 7" MAK and 8" SCT LX-series telescopes **$149.95** (20.00)
- Superwedge: recommended for Meade's 10" and 12" SCT LX-series telescopes **$395.95** (40.00)
- 14" Superwedge: heavy-duty design for Meade's 14" LX200™GPS-series telescopes **$429.95** (40.00)

Series 4000 Focal Reducers

f/6.3 Focal Reducer/Field Flattener

- 4-element, multi-coated
- Threads onto the rear cell of most SCTs
- Converts f/10 scopes to f/6.3 or f/6.3 SCTs to f/4
- Visual field is increased by 56%
- Reduces exposure times by about 50%

41mm clear aperture **$129.95** (5.26)

f/3.3 CCD Focal Reducer/Field Flattener

- 3-element, multi-coated
- Increased edge-of-field resolution and color correction
- Reduces CCD exposure times by up to 80%
- Threads onto the rear cell of most SCTs
- Variable T-adapter (included): f/3 and f/5 on f/10, 1.9 and f/3.2 on f/6.3
- Not for visual applications

41mm clear aperture **$149.95** (5.26)

Vibration Isolation Pads for Tripods

- Dramatically reduces vibration-damping time
- Recommended by top astronomers for any telescope

Set of 3 **$49.95** (7.02)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. The following national mail-order dealers carry Meade accessories in stock for immediate shipment:

ASTRONOMICS/Norman, OK
800-422-7876

OCEANSIDE PHOTO & TELESCOPE/Oceanside, CA
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AC Adapters

- **#541 AC adapter** for ETX-90, ETX-105, ETX-125, LX10 and LX90 **$49.95** (5.26)
- **#547 AC adapter** for LX200™GPS, LXD55, LXD75™ series telescopes **$69.95** (7.02)
- **#546 AC adapter** for ETX-70™, DS™-2000, NGC series telescopes **$19.95** (2.73)

THE DEEP SKY

The Milky Way cuts across the southern reaches of the constellation Cepheus the King, bestowing on it a nice mix of colorful stars and nebulae.

Most stargazers don't find Cepheus during their initial looks skyward because it is sandwiched between the more conspicuous constellations Cassiopeia and Cygnus. To trace its pattern, think of a child's drawing of a house: as a box with a tall triangular roof. Now look at the circular fold-out map and you should see it.

You can view Cepheus best under a dark sky far from city lights. It does not have dazzling jewels like some other Milky Way constellations, but instead shines with a quiet beauty. During a slow sweep of Cepheus, you can see brighter, colored stars floating on a vast carpet of background pinpoints. Here and there, darker fingers of obscuring gas and dust ooze in and out like waves surging softly up the beach.

Martin Ratcliffe *is former president of the International Planetarium Society.* Alister Ling *is a meteorologist for Environment Canada.*

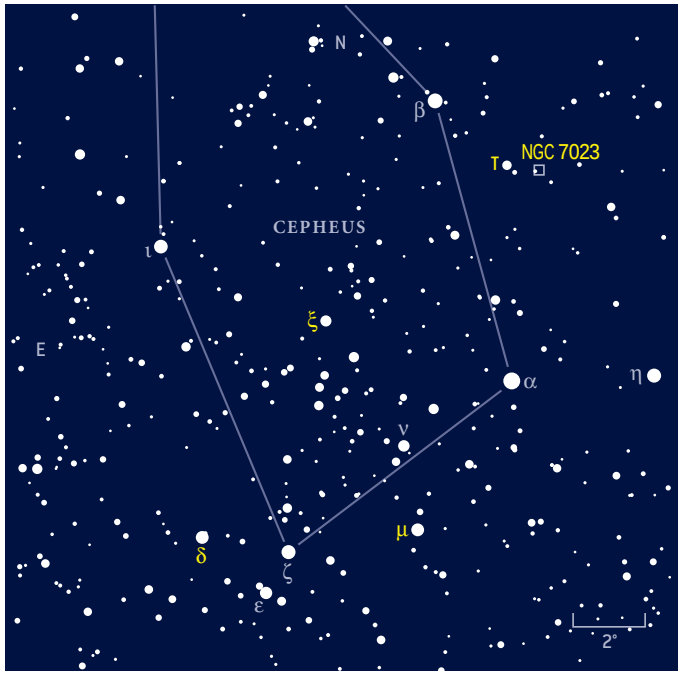
Kingly stars

Delta (δ) Cephei, best known as the grandfather of Cepheid variable stars, also deserves attention as a wide double star. Delta's brighter component glows yellow and shows a nice contrast to its fainter blue companion. Both appear readily at low power in any telescope. Be sure to take in the rich background, in many ways more beautiful than that surrounding the Cygnus doublet.

Smack in the middle of the "house" lies Xi (ξ) Cephei, a fine binary star that takes 3,800 years to complete one orbit. The 4.4- and 6.5-magnitude components appear 8" apart, five times closer than the Delta pair. The best view comes at magnifications above 100x.

During your binocular sweep, you likely noticed a lovely orange star at the base of the house. This is Sir William Herschel's "Garnet Star," although calling it a shade of red seems overly enthusiastic.

THE IRIS NEBULA (NGC 7023) reflects the light of a nearby hot star, giving this reflection nebula its characteristic bluish color. GEORGE GREANEY AND DEAN EASTON



A much stronger shade of orange will greet your eye when you point a telescope at the long-period variable T Cephei, which crests at the maximum of its 390-day cycle this month. T Cep should glow around magnitude 6.5. Check it every 2 weeks and you'll notice T dimming slowly.

A nebular nest

Sweep 1° west from T Cep and you'll land on the fascinating Iris Nebula. It was discovered October 18, 1894, by William Herschel. Before the Hubble Space Telescope captured a stunning image of this delicate reflection nebula, it was called simply by its catalog number, NGC 7023.

Nebulae come in four main flavors: emission, reflection, dark, and planetary. While planetaries result from the dying gasp of a single Sun-like star, the other three are closely related to one another. They arise from the gas and dust that abound in spiral galaxies.

In a reflection nebula, dust grains scatter starlight. As the amount of dust increases, the cloud turns distinctly blue, thanks to the same scattering effect that colors our daytime sky. When the cloud contains too much dust, starlight can't get through, resulting in a dark nebula. An emission nebula results if the star illuminating the cloud is massive and, therefore, hot enough to produce prodigious amounts of ultraviolet light. This high-energy radiation ionizes the surrounding gas and causes it to glow.

THE PLANETS

Two eclipses — a grand total eclipse of the Moon and a nice partial eclipse of the Sun — dominate a month that also features two bright planets approaching each other before dawn.

October 27 brings with it a total eclipse of the Moon. For some lucky observers, this will be their third view of totality in 17 months. It certainly ranks as the highlight of October for observers of the evening sky. An added spectacle for viewers far from city lights is the summer Milky Way, which remains visible in the early evening. But further delightful views await early risers. Four planets occupy the predawn sky — Venus, Mars, Jupiter, and Saturn — with Venus and Jupiter drawing closer as a prelude to their conjunction in early November.

This month's total lunar eclipse occurs on the evening of October 27 in North and South America and on the morning of October 28 in Europe. Observers in the East and Midwest will see the entire eclipse, while West Coast viewers will witness the Full Moon rising with a small bite already taken out of its lower edge.

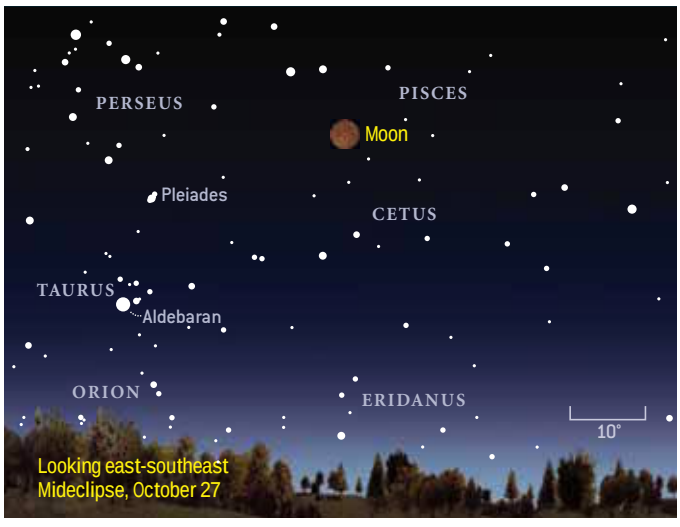
As the Full Moon slides slowly into Earth's shadow, the lunar surface appears black and white. The stark shadow looks deep and black, creating a harsh contrast with the sunlit portion. Gradually, as Earth's shadow envelops more of the Moon, subtle colors become apparent. Near the onset of totality, most of the Moon will take on an orange-red hue.

The exact appearance of the Moon depends on the state of our atmosphere. Astronomers estimate the brightness of an eclipse using the Danjon scale, which ranges from 0 to 4. If the Moon barely shows up, it ranks at 0 on the scale. At the other extreme, a value of 4 indicates a brilliant orange Moon. Most recent eclipses have been at the brighter end of the scale.

The times for the various stages of the eclipse are given below in Eastern Daylight Time. Subtract one hour to convert to CDT, two hours to convert to MDT, and three hours to convert to PDT. (Add five hours to convert to Western European Time, which puts this on the morning of October 28.) The eclipse begins when the Moon enters the light penumbral shadow at 8:06 p.m. The partial phase starts when the Moon enters the darker umbral shadow at 9:14 p.m. Totality commences at 10:23 p.m. and lasts until 11:45 p.m., with mid-totality coming at 11:04 p.m. The partial eclipse ends at 12:54 a.m., and the penumbral phase wraps up at 2:03 a.m.

The gas giants Uranus and Neptune share the stage with the eclipsed Moon, but they remain evening objects all month. Both planets can be spotted through binoculars, but if this is your first search for them this season, a star chart that reaches down to 8th magnitude will help.

THE FULL MOON takes more than 3 hours to traverse Earth's shadow October 27, giving observers a splendid eclipse view. JEFF WHIPPO



Uranus resides in the faint constellation Aquarius the Water-bearer. Aquarius does contain a recognizable pattern of five stars, however, known as the "Water Jar" and consisting of Alpha (α), Gamma (γ), Pi (π), Zeta (ζ), and Eta (η) Aquarii. Uranus lies about 10° south of the Water Jar, or 1.5 field diameters in 7x50 binoculars. You'll find a solitary, 4.8-magnitude star in the same region. This is Sigma (σ) Aquarii. Uranus lies 2° west of the star and, at magnitude 5.8, is the only other bright object in the vicinity. Through a telescope, Uranus reveals a tiny, 3.6"-diameter disk having a distinct blue-green color.

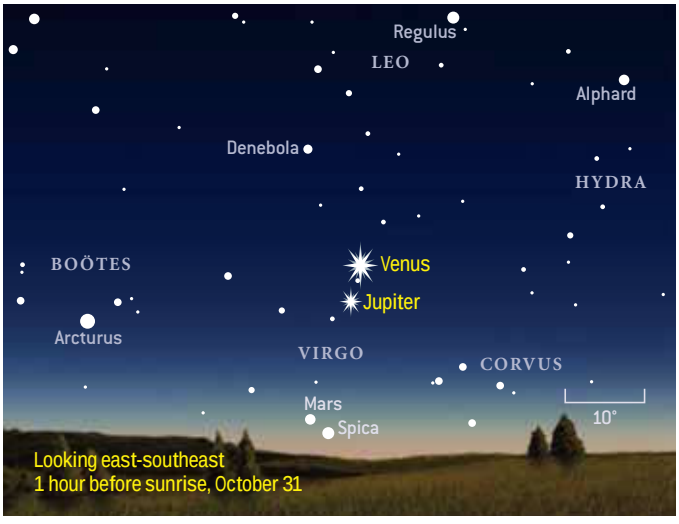
Neptune lies one constellation to the west of Uranus, in Capricornus the Sea Goat. You

can find Neptune 1.3° west of 4th-magnitude Theta (θ) Capricorni. Normally, a planet's motion from night to night will reveal its identity. However, Earth's own orbital path now carries us almost directly away from Neptune, so its westerly motion against the starry background slows to a crawl. On October 24, Neptune appears stationary relative to the stars, then it begins to move slowly eastward. The planet glows faintly at magnitude 7.9 and, through a telescope, shows a 2.3"-diameter, blue-gray disk.

No other planets grace the evening sky, and the planetary action shifts to the early morning. Saturn appears first, rising above the east-northeastern horizon around 1 a.m. on October 1. By month's end, Saturn rises well before midnight thanks to the one-hour change in clocks on the 31st. The ringed planet lies south of the bright twin stars, Castor and Pollux, in Gemini. A waning crescent Moon lies between Pollux and Saturn on the morning of October 7.

Excitement will run high as the Cassini spacecraft makes its first close flyby of Saturn's largest moon, Titan, on October 26. You can spot Titan for yourself with a small telescope. Glowing at magnitude 8.3, the moon lies due north of Saturn on October 11/12 and 27/28 and due south of the planet on October 4 and 20. On the morning of October 25, Titan and enigmatic Iapetus lie less than 1' apart. Titan will appear about 15 times brighter than Iapetus, a moon whose brightness varies by a factor of five during the course of its orbit.

The next planet to rise is brilliant Venus. Shining at magnitude –4.1, it outshines every other object in the night sky except the Moon. On October 3, Venus rises around 4 a.m. and lies next to Regulus, the brightest star in Leo the Lion. This rare close conjunction places both objects within the same telescopic field of view. At their closest, only 9' separate the pair. Regulus shines at magnitude 1.4, so the two differ by a little more than five magnitudes (a factor of one hundred) in brightness.



A CRESCENT SUN prepares to set during the July 1990 solar eclipse. A similar view awaits those in Alaska and Hawaii October 13. CLARK SNURE

Throughout the month, watch Venus as it falls toward Jupiter. The giant planet rises barely before dawn in early October but climbs away from the horizon each day. By October 10, a crescent Moon lies 5° above Venus while Jupiter lies 25° below. Two mornings later, the waning Moon passes 4° above Jupiter.

Venus and Jupiter continue to close on each other through the remainder of October. By the 31st, the pair stands just 5° apart. With Jupiter then clearing the eastern horizon just after 4 a.m., the giant planet presents an early opportunity for viewing its cloud belts. Through a telescope, Venus shows a three-quarter-lit disk that appears less than half the diameter of Jupiter's, which now stands at 31" across. Venus and Jupiter will pass less than 1° apart during the first week of November.

Mars rises about an hour before the Sun October 31 and lies 3° north of Spica, the brightest star in the constellation Virgo. The Red Planet has begun a slow climb toward opposition late next year.

A partial solar eclipse occurs on October 13/14 and can be seen from Japan, northeastern Asia, Alaska, and Hawaii. The peak of this eclipse is visible from western Alaska on the evening of the 13th, beginning around 6 p.m. local time. An hour later, the partial phase reaches its maximum with 93 percent of the Sun eclipsed. Residents of Anchorage will witness a lovely crescent Sun as it sets. In Hawaii, the eclipse begins at 5:15 p.m. local time and the Moon covers 50 percent of the setting Sun.

METEORS AND MOONS

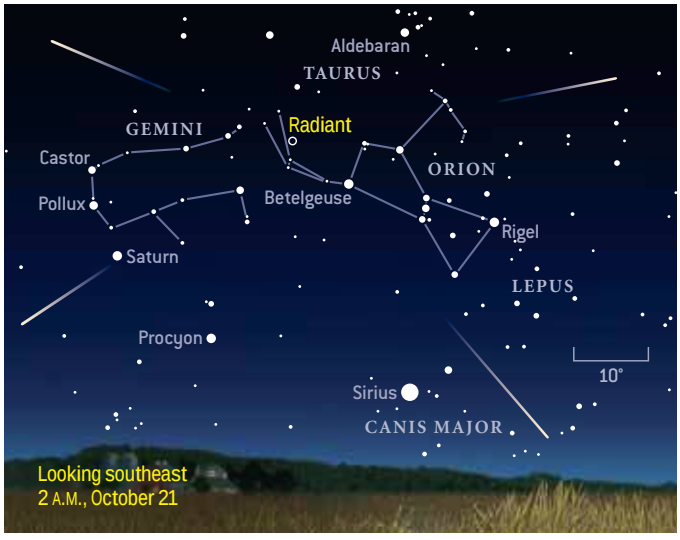
Earth sweeps up debris left behind long ago by Comet Halley, creating a nice meteor shower unaffected by moonlight. When the Moon is visible, check out its ancient crater Fracastorius.

Halley's children

The Orionid meteor shower peaks this year on the night of October 20/21. This coincides with the First Quarter Moon, which sets shortly before midnight. That means as the radiant climbs higher in the eastern sky during the early morning hours, there won't be any moonlight to interfere with meteor viewing.

Orionid meteors result when Earth encounters the stream of debris deposited by Comet Halley during its countless trips around the Sun. The Orionids are one of two annual meteor showers, the other being the Eta Aquarids of May, that trace their origin to this famous comet. As their name implies, Orionid meteors appear to come from Orion the Hunter, in the northernmost part of that constellation. Because they radiate from a more northerly declination than do the Eta Aquarids, Northern Hemisphere observers get a much better view of the Orionids.

An observer under a clear, dark sky often can see 15 to 20 meteors per hour at the peak of the Orionids. Those in typical residential areas should expect no more than about half that number. The period of activity for the Orionid shower spans from October 2 through November 7, with much lower rates the further you stray from the peak night.



Earth encounters Halley's debris stream at great speed: some 40 miles (66 km) per second. That explains the high rate of bright meteors. Many of these give birth to persistent trains — embers from the passing fragment that leave the atmospheric trail glowing for perhaps a minute after the meteor itself flames out.

An ancient crater

One of the most recognized features on the Moon has to be Mare Tranquillitatis, famous as the landing site of Apollo 11. Connected to the southern edge of Tranquillitatis is a much smaller mare, Nectaris. And at the southern border of Mare Nectaris lies the ancient, eroded crater Fracastorius.

The northern wall of this 77-mile-wide (124 km) crater all but disappeared when molten lava flooded the crater approximately 3.7 billion years ago. The flooding almost buried the central mountain peak, and the crater's floor appears to continue right into Nectaris. The southwestern wall of Fracastorius also appears to be breached, this time by a line of multiple craterlets that terminates in a larger secondary crater on the western wall.

The best views of Fracastorius come when the Sun rises over the region, between 5 and 6 days after New Moon. This month, that corresponds to the evenings of October 18 and 19. A few days after the Sun rises (near the time of First Quarter Moon), the Sun illuminates the crater's entire floor. That's a good time to search for the dozen or so tiny craters that dot the floor of Fracastorius. How many of them can you spot?

THE CRATER FRACASTORIUS sits at the southern end of Mare Nectaris. The crater's northern wall nearly disappeared when lava flooded it 3.7 billion years ago. GÉRARD THERIN

COMETS AND ASTEROIDS

A trio of modest comets brightens the evening sky, making good targets for those with small telescopes. Meanwhile, the brightest asteroid continues to be a nice subject for binoculars.

Comet feast finished

Talk about luck: In the space of less than one year, we saw three naked-eye comets and two binocular ones. Experienced observers know this kind of treat is extremely rare. In contrast, October's comets are more typical. They require a moonless sky (which occurs near midmonth) and an observing site well outside the city for a decent view.

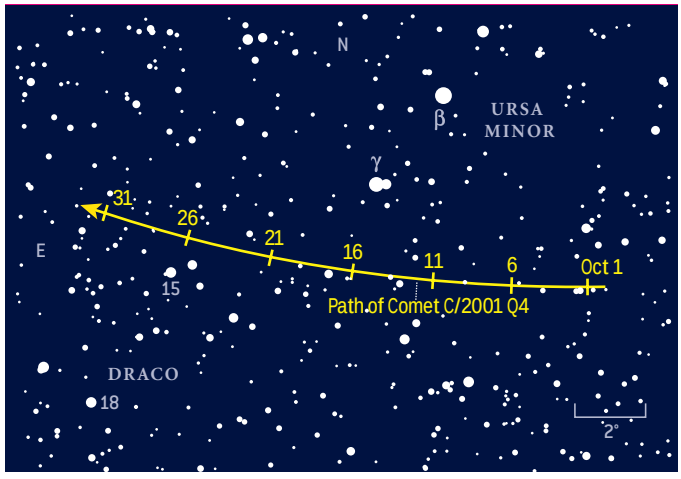
Six months after its lovely display, Comet C/2001 Q4 (NEAT) tracks slowly across the far north, a faint echo of its glory days when it featured a greenish head and blue ion tail. Glowing at 10th magnitude, Q4 remains visible all night near the "guardians of the pole": Beta (β) and Gamma (γ) Ursae Minoris. Some observers mistake Beta, also known as Kochab, for Polaris because the two shine with similar intensity.

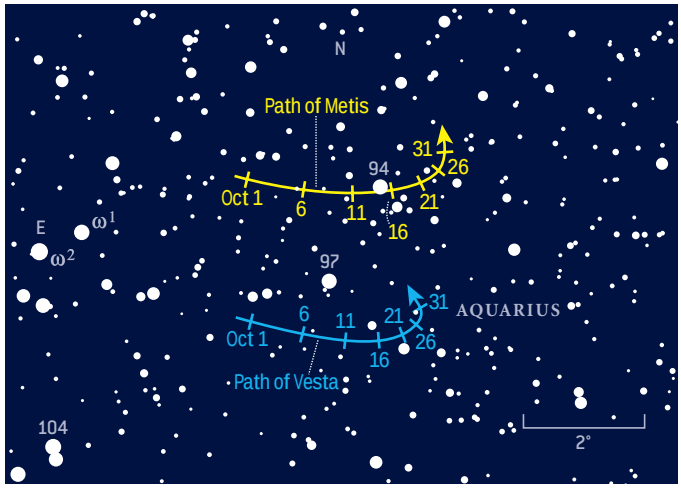
If predictions hold true, Comet C/2003 T4 (LINEAR) should approach naked-eye visibility early next year. During October, T4 slides along the tail of Draco, glowing at 12th magnitude as it accompanies Q4 in a tight circle around the pole.

Most of the bright comets that visit the inner solar system pass through only once. Yet many comets orbit the Sun on long elliptical paths, returning periodically on time scales of a few years to centuries.

Comet 78P/Gehrels comes back every 7.2 years. (The number 78 means it was the 78th comet recognized as periodic, hence the P.) At its closest approach to the Sun, Gehrels comes no closer than twice Earth's distance from the Sun, placing it outside the orbit of Mars. This apparition is as good as it's going to get because the comet hits peak brightness when Earth lies closest to it. Because it measures only a mile or so across and remains far from the Sun, Gehrels should reach only 11th magnitude, about the same brightness as a typical galaxy on the Messier list.

Gehrels appears best after 10 p.m., when it has risen in the east just to the right of the beautiful Pleiades star cluster. No galaxies or other deep-sky objects that could deceive you inhabit the area. This comet likely will have a bright, nearly stellar point surrounded by a circular fuzz. Its tail probably will be hidden from view, pointing behind it and away from both the Sun and Earth.





A binocular asteroid

One benefit of tracking bright asteroids is that you get a chance to appreciate the extent of a constellation you otherwise might ignore. Aquarius, like its neighbor to the west, Capricornus, contains only a couple of stars readily visible from an urban backyard. Under a dark country sky, however, a beautiful, delicate outline of 4th-magnitude stars adorns Aquarius.

Grab your binoculars and slide two fields of view north of Fomalhaut, the sparkling bright star that appears by itself low on the southern horizon. You'll land on 97 Aquarii, the lone bright star in a half-circlet of wide doublets and triplets that forms the bottom end of Aquarius.

Asteroid 4 Vesta will be the next brightest object just below 97 Aqr, glowing at magnitude 6.7. If you return every two or three nights, you will notice the asteroid's telltale displacement against the background stars. Vesta reached opposition in September, so it now appears highest in the south during late evening.

As a challenge, see if you can spot 9 Metis, Vesta's faithful traveling companion these past few months. Metis lies just over 2° north of Vesta but glows considerably fainter at magnitude 9.7.

Anyone can sell you a telescope.

Selling you the right telescope means listening carefully to what *you* want to see and do with a telescope – to match your needs and dreams to your budget. It means answering your questions truthfully and fully. It means taking the time to explain your options. It means using our more than 160 years of experience in using and selling telescopes to make sure that you get the scope and accessories that work together properly and do what you want to do . . . the scope and accessories that are right for *you.*

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs (and your budget) from the hundreds of telescopes we stock. And, with our seven-figure inventory, we can usually ship you the right scope right away.

We started ***astronomics*** over 25 years ago because we loved astronomy, not just as a business. Our sales may have grown over a thousand-fold since that first year, but we're still the same family-owned, family-run, full-line telescope dealer we were in 1979. And we still love astronomy.

astronomics. No hard sell. No guesswork. Just honest advice, the time to make sure you get the right telescope and accessories, and a good price. Call us toll free at (800) 422-7876 and find out for yourself.

We ship Meade LX200GPS-*SMT* go-to scopes from stock.

Meade 8" LX200 GPS SMT **$2195**

Meade prices are about the same anywhere you call. So why order a 7" to 10" Meade LX200 from a dealer who charges your credit card, then makes you wait and wait until he gets around to ordering? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

Meade LX200GPS scopes have performance and features galore. Optional UHTC optics can increase light transmission by as much as 20% so you can see 20% more of the Universe.

A *fully automatic* GPS system takes the time out of setting up your LX200 and aligning it on the sky. You start observing in minutes.

Smart Mount Technology can improve your scope's pointing accuracy as you observe. A supplied Lunar Planetary Imager takes digital color pictures for you.

The Autostar computer has a built-in database of over 145,000 stars and objects. It will find any of them for you *automatically*. You'll spend more of your time looking *at* heavenly bodies and less time looking *for* them.

Optional Meade Sky Assurance™ extended service programs can extend your telescope warranty to three or five years – *or longer!*

Here are the LX200GPS scopes we ship from our stock:

7" Maksutov-Cassegrain ..... **$2695**[00]
7" Maksutov-Cassegrain, w/UHTC ..... **2845**[00]
8" Schmidt-Cassegrain ..... **2195**[00]
8" Schmidt-Cassegrain, w/UHTC ..... **2370**[00]
10" Schmidt-Cassegrain ..... **2745**[00]
10" Schmidt-Cassegrain, w/UHTC ..... **2980**[00]

Here are the LX200GPS scopes Meade ships from the factory due to their weight:

12" Schmidt-Cassegrain ..... **$3595**[00]
12" Schmidt-Cassegrain, w/UHTC ..... **3890**[00]
14" Schmidt-Cassegrain ..... **4995**[00]
14" Schmidt-Cassegrain, w/UHTC ..... **5345**[00]
16" SCT, w/altazimuth pier and UHTC .... **15,645**[00]
16" SCT, w/equatorial pier and UHTC ..... **15,845**[00]

We actually stock TeleVue. Does your dealer?

NP-101 **$3595**

Other dealers may say they carry TeleVue, *but we actually keep TeleVue in stock.* Lots of it. We keep a healthy six figure TeleVue inventory in stock, so we can ship your TeleVue fast.

Here are some of the TeleVue apo refractors we have available for immediate shipment.

TV-76, 3" f/6.3, ivory or evergreen ..... **$1675**[00]
TV-85, 3.35" f/7, ivory or evergreen ..... **2080**[00]
TV-102, 4" f/8.6, ivory ..... **2635**[00]
Renaissance 102, 4" f/8.6, brass ..... **3175**[00]
NP-101, 4" f/5.4, ivory ..... **3595**[00]

All of these refractors come without a mount, but include an eyepiece (except the NP-101), an enhanced aluminum or Everbrite 99% reflectivity star diagonal, a carrying case, and a tube ring for mounting. Optical tubes only, without these accessories (such as the new **TV-60** apo at $795), are also in stock.

Whether it's a Gibraltar, Panoramic, or Tele-Pod mount; a Sky Tour computer; a Nagler, Radian, Panoptic, or Plössl eyepiece; a Powermate or Barlow; an Everbrite 99% reflectivity star diagonal; a light pollution filter, or a BinoVue – if it's TeleVue, it's in stock.

> Just wanted to thank you for the fantastic service. I know it's a benefit that I live relatively close to your office, but I never expected my order to be processed and shipped so quickly! I wish every mail order business could work like you. **Customer Quote of the Month #151**

Everyone can afford CCD when cameras start at $249!

Low cost **SAC Imaging** CCD cameras finally make serious CCD imaging possible at sensible prices. Even the owners of small telescopes such as the Meade ETX-90 can do serious CCD imaging with a very affordable SAC camera.

SAC7B cooled 24-bit color **$499**

Whether it's short exposure lunar and planetary shots, long exposure deep space photos, black and white imaging, single-pass full color, tri-color with a filter wheel, or auto-guiding – there's an inexpensive SAC CCD camera to do it. You'll find full details and pricing on all of them on our website at **www.astronomics.com**.

New Meade LXD75 scopes make astronomy easy.

6" Meade SN-6 AT Schmidt-Newtonian **$799**

Even if you don't know the skies at all, you won't spend all of your time hunting for planets and deep space wonders with one of the new and enhanced **Meade LXD75** go-to reflectors, refractors, or Schmidt-Cassegrains.

A few touches on the scope's Autostar hand control speeds your LXD75 to any of 30,000+ stars and objects in its memory and tracks it accurately for as long as you want to observe. You spend more of your time looking *at* celestial objects and less time looking *for* them with a Meade go-to LXD75.

Each has a tubular steel leg adjustable height tripod, dual motor drives, finderscope, eyepiece, illuminated polar finder, Lunar Planetary Imager digital camera, and Autostar computer to take the guesswork out of finding your way around the skies.

8" Meade SC-8 AT Schmidt-Cassegrain **$1299**

There are new extended shopping hours at astronomics . . .

For your convenience, we've extended our telephone hours until 9 PM CST Monday through Friday. You can call late and still get the friendly, reliable Astronomics service you've come to rely on for more than 25 years. Our regular telescope experts will be available to answer your questions, not just an order taker – so you can call us late for all your telescope needs!

Our *38* light pollution filters make bright skies dark.

Are city lights washing out your view of the skies? Improve your deep space observing by dimming those annoying lights with one of the many light pollution reduction filters we stock.

Some dealers carry only a few filters to reduce the effects of light pollution. We carry 38. We have one that's exactly right for you.

We have two **Celestron** broadband filters. One is designed for 1.25" eyepieces; the other for Schmidt-Cassegrain (SCT) rear cells.

We have 13 **Lumicon** Deep Sky broadband, UHC narrowband, and H-Beta and Oxygen III line band filters for use in 1.25" and 2" eyepieces, as well as on SCT rear cells.

We have six **Meade** broadband, narrowband, and Oxygen III filters in 1.25" eyepiece and SCT rear cell versions.

We have four **Sirius** contrast enhancement and nebula filters for 1.25" and 2" eyepieces, plus a unique 1.25" *variable* nebula filter.

We have four **TeleVue** Bandmate NebuStar UHC-type narrowband and Oxygen III line band filters in 1.25" and 2" eyepiece versions.

We have eight **Thousand Oaks** broadband, narrowband, Oxygen III, and H-Beta filters in both 1.25" and 2" eyepiece versions.

Why wait for another dealer to *order* your scope? We'll ship your Meade LX90 from our stock *now.*

$1695

Some dealers don't even stock the telescopes they sell. Why wait for a non-stocking dealer to finally get around to ordering an LX90 for you to enjoy?

The LX90 is almost always in stock at ***astronomics.*** We had over a dozen in inventory as this was written, so you can probably get *your* LX90 from us with little or no delay.

The **Meade LX90** 8" Schmidt-Cassegrain lets you enjoy go-to astronomy for not a lot of money. The LX90 costs only $1695. For that price you get a heavy-duty adjustable height tripod; 26mm Super Plössl eyepiece; an Autostar computer hand control with a memory of 30,223 stars, planets, and deep space objects it can find and track for you; a big 8 x 50mm finder; and more. It's a lot of telescope for a very reasonable price.

Only $995 for a 5" GPS-ready Celestron SCT.

The **Celestron NexStar 5i** is the *only* 5" telescope that has automatic GPS satellite alignment available as an option. The NexStar 5i has a computer hand control with a 45,000+ star and object database, adjustable height tripod, red dot finder, eyepiece – everything you need to start observing immediately!

Multicoated optics are *standard equipment* with the Celestron NexStar 5i, not an option as with other scopes. NASA uses Celestron 5" multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium image quality?

the Nexstar 5i is shown with optional photography accessories **$995**

Discovery Dobs are not cheap . . . just inexpensive.

8" f/6 DHQ **$449**

Why settle for a Dobsonian with mass-produced so-so imported optics when premium made-in-the-USA optical quality costs no more?

Discovery's optics are made to 1/10th wave accuracy by experienced optical craftsmen in California, one high quality mirror at a time. The 6" to 13.1" Discovery DHQ Dobsonians have a fast cool-down open back metal mirror cell, a thin vane diagonal spider, *two* 1.25" Plössl eyepieces, 2" metal rack and pinion focuser with 1.25" adapter, built-in tube balance system with oversized bearings, 6 x 30mm finder, tube carry handle, and tube end dust cover.

Here are the prices for the fully-equipped Discovery DHQ Dobsonians. Freight from the factory in California is additional, as shown.

6" f/8 Discovery DHQ ..... **$339**[00] + $49 freight
8" f/6 or f/7 Discovery DHQ ..... **449**[00] + $49 freight
10" f/4.5 Discovery DHQ ..... **649**[00] + $69 freight
10" f/5.6 Discovery DHQ ..... **649**[00] + $69 freight
13.1" f/4.5 Discovery DHQ ..... **999**[00] + $185 freight

Big right angle finders. Not-so-big prices.

Antares 12 x 80mm **$174**[95]

Antares 8 x 50mm and 12 x 80mm right angle finders are affordably priced from $79[95] to $239[95]. You can get yours in a Celestron black, Meade blue, or gloss white finish. Choose from either a standard erect mirror image or an erect right-reading image that shows you the sky the way it appears on star charts. Each is available with dark crosshairs or with a unique built-in cordless red disk illuminator. Economical optional quick release mounting brackets are also available.

astronomics

Our 26th year of friendly service, good advice, and money-saving prices.

680 24th Avenue SW, Norman, OK 73069

Toll-Free Telephone: **(800) 422-7876** Alternate Telephone: **(405) 364-0858**

We'll sell you the *right* telescope.

25 years later . . . *still here and still growing.*

Reprinted below is one of our first ads, from 1979. Some things have changed – my beard is gray, my hair is thinner, and most of the other stores open in 1979 are now out of business.

2140
"This is my personal telescope.
I'll sell you one just like it ...at a big savings."
Why? Simple. Telescopes aren't my only business. I don't have to make a big profit on each telescope to pay office rent and salaries – my other business takes care of that.
I sell telescopes because I love astronomy. I sell them as cheaply as possible so that more people can enjoy it as much as I do.
So before you buy a Celestron, Astroscan, or an accessory for either, drop me a line. I think I can save you some money.
Ad-Libs Astronomics
2140 Melrose Court, Norman OK 73069
(405) 364-0858
Celestron International
©1979 by Ad-Libs Advertising, Inc.
AMERICAN
VISA

But some things haven't changed. Our phone number is still the same. I'm still wearing the same wristwatch as in the picture. And I still sell telescopes because I love astronomy.

In 1979, a discount on a telescope was unheard of. The only way I could get one for less than list price was to become a dealer myself – to buy a dozen scopes, keep one, and sell the rest. So I gave it a try.

Our main business was an advertising agency called Ad-Libs Advertising. We were too small to afford two telephone lines in '79, so we called the telescope company Ad-Libs Astronomics. That way, we could answer "Ad-Libs" when our only phone rang and be right whether the caller wanted a telescope or an advertising campaign. We dropped the "Ad-Libs" when we started selling enough telescopes to afford another phone line.

My 7-year old son kept the inventory on filing cards in '79. Now he runs the place with a 17-computer network.

Yes, a lot has changed in 25 years, but some things are still the same. I still love astronomy as much as I did when I got my first telescope in 1952. And I still sell telescopes as cheaply as possible so that more people can enjoy astronomy as much as I do.

Denkmeier Binoviewers are optimized for *your* scope.

Use both eyes to observe through a **Denkmeier Binoviewer**, and you see up to 40% more detail than you can when looking through a single eyepiece. Your views of the planets, Moon, and deep space objects become almost three-dimensional.

Whether you have a refractor, reflector, or a Schmidt-Cassegrain, there is a Denkmeier Binoviewer with specialized optics that are optimized to give you peak visual performance with your scope's particular optical design. Prices start at $599.

New lower-priced SBIG ST-7XME CCD cameras!

SBIG has reduced the price of their ST-7XME self-guiding CCD camera, and added new versions for as little as $1495!

The ST-7XME Standard is now only $1995. It includes a microlens Class 2 imaging detector with no column defects, large TC-237H guiding detector, custom case, high speed USB interface, thermoelectric cooling with whisper fan, and more.

The new ST-7XME Deluxe upgrades the standard model to a Class 1 detector, and adds CCDSoft version 5 image processing software and other accessories. At only $2495, it's $200 less than the original ST-7XME.

The ST-7XMEI drops the guiding detector and some accessories from the Standard camera (you can add them later if you need them), to give you a premium CCD imaging camera, without built-in self-guiding, for only $1495!

Sell your used telescopes and accessories quickly *for free* by using the no-charge classified ads at
www.astrofieds.com

Get your go-to *now.* We ship Celestrons from stock.

Why wait for another manufacturer to build and ship a scope to you? We ship **Celestron Advanced Series** go-to telescopes from *our* stock daily. These Celestron scopes put multicoated optics on an easy-to-use go-to mount. From a 5" Schmidt-Cassegrain (with optics so good that NASA flies them on the Space Shuttle) to a 10" reflector, there's a Celestron go-to that's right for you and your budget. Scopes available from stock include:

a 6" Newtonian reflector	$799.00
an 8" Newtonian reflector	1019.00
a 6" achromatic refractor	1069.00
a 5" Schmidt-Cassegrain	1099.00
a 10" Newtonian reflector	1199.00
an 8" Schmidt-Cassegrain	1359.00
and a 9¼" Schmidt-Cassegrain	1779.00

Each Celestron Advanced Series go-to telescope has a heavy duty adjustable height tripod with sturdy 2" diameter tubular steel legs. A built-in computer takes the guesswork out of finding your way around the skies. It can find and track over 45,000 stars and objects for you, compared to 30,000 for the competition. And multicoated optics for extra-bright images are standard, not an optional extra.

and a new improved website at www.astronomics.com!

We've added more products and features to our website. There are calculators – for CCD cameras, eyepieces, Barlows, camera adapters, and more. You can do side-by-side product comparisons. Looking for a particular product? We tell you if you can save money on a used one. And that's just a taste of the expanded Astronomics website features in store for you.

$399.95 for a 130mm Mak . . . $209.95 for a 90mm.

The new 5.1" **Celestron C130M Maksutov** has a dovetail that will let you install it on a $399 Celestron CG5A German equatorial mount (or on a $749 Advanced Series go-to mount), as well as on a standard photo tripod. You get the best of all worlds – astronomical viewing as well as terrestrial. The C130M has a big 10 x 50mm finder, dust caps, 45° image-erecting diagonal for nature studies (as well as a built-in 90° star diagonal for sky viewing), 32mm 1.25" Plössl eyepiece (64x), a soft case, and more.

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a 1.25" eyepiece adapter to the left (our #WSCTF) is only $149. As with all William Optics scopes and accessories, it offers exceptional value – fine optical performance and quality mechanics, at a price less than similar competitive products.

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The 2" rotatable Schmidt-Cassegrain zero image shift Crayford-style manual focuser with

The **William Optics Megrez 80 II APO** *fluorite triplet* 80mm f/6.25 apochromatic refractor optical tube to the right has outstanding optics – truly excellent color correction, very high contrast, tack sharp images – for *$200 less* than a competitive triplet apo that's similarly equipped.

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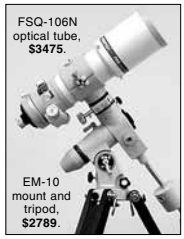
Takahashi's unique 90mm f/5.6 **Sky 90 II** is sale priced at **$2049!** Regularly $2479, you save $430! *Sky & Telescope* called this compact scope "an ideal travelscope for mobile observers, providing maximum performance at minimum size."

The latest 4" **FS-102 II** fluorite doublet with sliding dew shield is **only $2095**! Regularly $2549, you save $454!



The 5" **FS-128** fluorite doublet is **only $4495**! Regularly $5249, you save $754!

Finally, the big 6" **FS-152** fluorite doublet optical tube is on sale for **only $6995**! Regularly $9329, you save $2334!

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ASK ASTRO

Signal vs. noise, what's "right" with right ascension, inside gas giants

SIGNAL VS. NOISE

How can CCD images just a few minutes long be combined into one photo that shows details not visible in the originals? — ROBERT BAILEY, ROCKFORD, ILLINOIS

THIS BEAUTIFUL RENDITION of the Rosette Nebula is made from 14 separate CCD images. California astrophotographer Daniel Phillips combined images taken from observing sessions separated by several months. Most exposures were less than 30 minutes long, but the combined image has an effective exposure of more than 3 hours. DANIEL PHILLIPS

The details aren't visible in the individual images, but they are present. You can't see them because they are hiding in the noise. Combining images reduces noise, and the details become visible.

This sounds like magic, but it's really just mathematics at work. Noise isn't a "thing" in the usual sense. It is a measure of uncertainty in the data. In each image, there is a large uncertainty in the brightness value of each pixel. Some pixels are brighter than they should be, and some of them are fainter than they should be. The range of these variations is a measure of the noise present in an image.

Most of the noise comes from two sources: read noise and shot noise. Read noise occurs each time you read an image out of the camera. Shot noise accumulates over time just like the image signal does, but the shot noise is equal to the square root of the signal. So if you double the exposure time, the signal increases by a factor of 2, but the noise increases only by the square root of 2, or 1.4. For longer exposures, signal increases faster than noise, uncertainty goes down (each pixel's brightness is more accurate), and details become more visible. In practical terms, any brightness difference that is smaller than the noise level will be lost to view. Lowering the noise level with a long exposure time effectively brings out these brightness differences.

You can get a long total exposure time either with a single long exposure or by adding multiple short exposures together. The read noise is included only once for a single long exposure, but "n" exposures will add "n times the read noise" to the final result. So "stacking" (combining) images is a little noisier than a single exposure, but it is much more convenient — especially if you are gathering data on multiple nights. Short exposures also are less risky, because something like a passing satellite will only ruin one of the short exposures. — RON WODASKI, *THE NEW CCD ASTRONOMY, www.newastro.com/ipb*

WHAT'S "RIGHT" WITH RIGHT ASCENSION

What is the source of the term "right ascension"? Why is it right ascension and not simply ascension, as with declination? — JACK WHITMAN, PHILADELPHIA

Right ascension is based on the apparent rotation of the sky as Earth spins — 360° in 24 hours, or 15° per hour. The concept dates at least from the time of Hipparchus (190–120 B.C.). Right ascension and declination together form the widely used equatorial coordinate system astronomers use to describe the positions of celestial objects.

Imagine the sky as the inside surface of an enormous sphere. Earth floats in the center of this sphere so that its spin axis aligns with the North and South Celestial Poles. Earth's equator, projected onto the sphere, becomes the celestial equator; lines of declination in the sky match up with parallels of earthly latitude. A 15° span of the celestial equator equals the sky's westward motion in one hour of time, and thus one hour of right ascension. Astronomers

measure right ascension eastward along the celestial equator, starting from the Sun's position at the spring equinox (also known as the "first point in Aries").

If we viewed the sky from Earth's equator, the celestial poles would lie on the horizon and the celestial equator would arc directly overhead, passing through the zenith. This orientation makes the celestial sphere a "right sphere," one in which the horizon meets the celestial equator at 90°. The stars now rise at a right angle to the horizon, and all objects on the same arc of right ascension rise together.

But suppose we move away from Earth's equator. Now the celestial equator meets the horizon at an oblique angle, that is, one other than 90°. Astronomers once referred to "oblique ascension," an angle measured along the celestial equator from the spring equinox to where a point of interest meets the horizon. The term is now used so rarely that many professional astronomers have never heard of it. Oblique ascension refers positions to the horizon, so a given value applies only to observers at the same latitude, whereas right ascension describes sky positions for any observer on Earth.

While "ascension" refers to rising stars, astronomers once also used right and oblique "descensions" based on setting stars. Today, only right ascension survives in astronomy, although the other terms find occasional use in astrology texts.

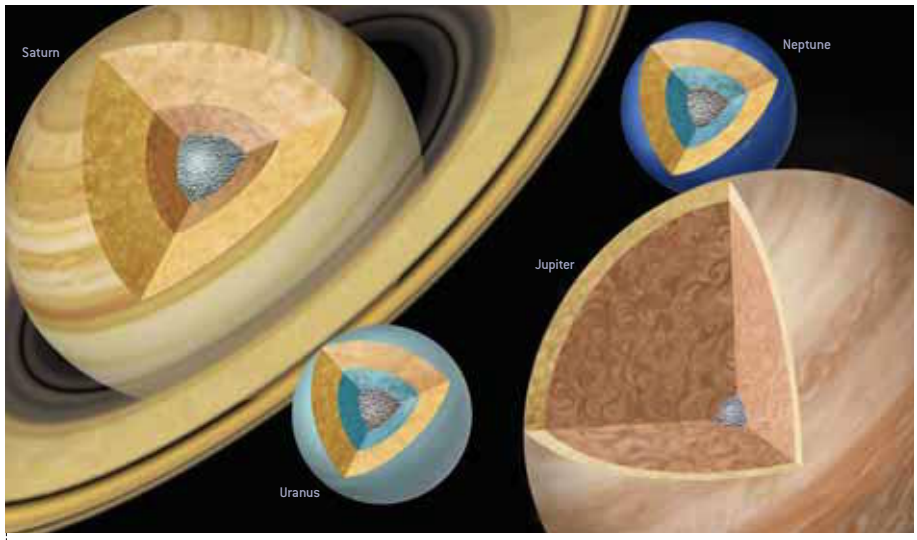
We thank James Hilton of the U.S. Naval Observatory and Brent Archinal of the U.S. Geological Survey for their help in answering this question. — FRANCIS REDDY, ASSOCIATE EDITOR

INSIDE GAS GIANTS

Do the giant planets — Jupiter, Saturn, Neptune, and Uranus — have solid cores? If so, what are they made of?

— RAMON S. LOPEZ, WOODLAND, CALIFORNIA AND WOODY HAVENS, NEWCASTLE, OKLAHOMA

Observations of the four jovian planets, which have low average densities, show they are mainly composed of the light elements hydrogen and helium. But are they mostly gaseous, liquid, or solid?



DEEP WITHIN THE ATMOSPHERES of the solar system's giant planets, pressures and temperatures rise to the point where atmospheric gases turn into liquids. At their centers, under tremendous temperature and pressure, lie solid cores of ice and rock. Saturn's core (top left) ranks largest, with a mass 15 times that of Earth. *ASTRONOMY*: JAY SMITH

Actually, the gaseous component forms less than the outer 10 percent of Jupiter and Saturn. These so-called gas giants are large and massive enough that in deep layers, under high pressure, the dense gas changes to liquid. The transition from gas to liquid is quite gradual. A more distinct change occurs at pressures of 1.4 million Earth atmospheres, about 4,500 miles inside Jupiter (10 percent of the radius) and 19,000 miles inside Saturn (50 percent of the radius). There, liquid molecular hydrogen transforms into a substance known as liquid metallic hydrogen, which conducts electricity. Currents in this liquid layer generate the powerful magnetic fields of Jupiter and Saturn.

In fact, it would be more precise to call the jovian planets "liquid giants." Rotation flattens them at the poles, but the amount of flattening depends on how much solid matter exists within the planet. Jupiter's polar diameter is about 6-percent less than its equatorial diameter, which implies that Jupiter must have a rocky core 10 times more massive than Earth (but only 3 percent of Jupiter's mass) and about 1.5 times Earth's diameter. Saturn, which is flattened at the poles by about 10 percent, must have a larger and less-compressed core. It's about 2.5 times the size of Earth and contains about 15 times Earth's mass.

These cores are solid because they are under high pressure. In Jupiter's case, the pressure is 40 million atmospheres, and the temperature is about 23,000 kelvins (41,000° F). An ice-rich outer core surrounds its inner rock core, which contains iron and silicon. Here, ice refers to substances like water, ammonia, and methane. Despite the heat, these substances remain in a solid state because of the enormous pressure on them. Planetary scientists call this sort of ice-rock mixture a "clathrate."

Uranus and Neptune are much less massive than Saturn, so pressures within them never reach more than 100,000 atmospheres — pressures too low for liquid molecular hydrogen to turn into metallic hydrogen and become electrically conductive. Nevertheless, both planets have strong magnetic fields. Scientists believe that these planets generate their magnetic fields in a hot, swirling mixture of water, ammonia, and methane beneath their hydrogen layers. Both Uranus and Neptune have rock-ice cores of about 1.2 Earth diameters and about 10 Earth masses. For both planets, these cores constitute a large percentage of their interiors: 60–70 percent of the mass, 30–40 percent of the radius. — RICHARD CROWE, UNIVERSITY OF HAWAII — HILO

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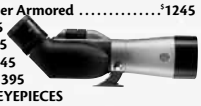

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Anyone with a 6-inch or larger telescope can watch a Gibraltar-size space rock as it screams past our planet. /// BY ALISTER LING

Toutatis shoots past Earth

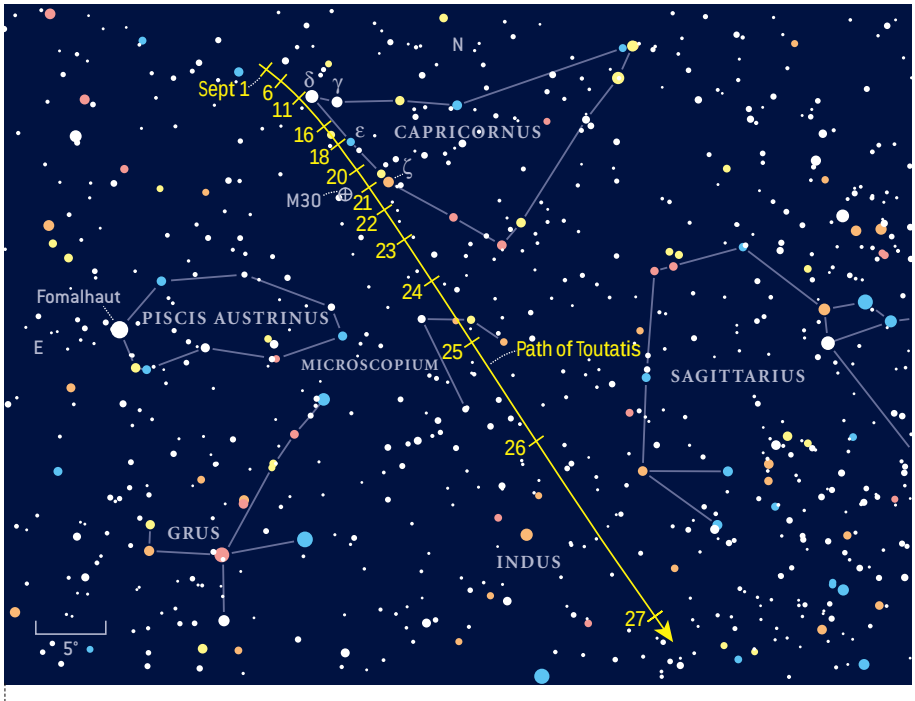
On September 29, a rocky asteroid

named Toutatis will whiz silently past Earth, coming no closer than four times the Moon's distance. Astronomy has its share of uncertainties in measurement and prediction, but this astronomical close shave certainly won't touch a hair. Instead, the "impact" of Toutatis lands on our intellectual side.

If Toutatis were to strike Earth, the impact would unleash the equivalent of about 1 million megatons of TNT, completely dwarfing any hydrogen bomb explosion. This would be catastrophic on a global scale — although still somewhat less than the impact that caused the extinction of the dinosaurs and other life forms 65 million years ago, if that's any reassurance. But by any measure, such an impact is sobering to think about.

Will humanity ever be on the receiving end of a celestial cannonball? To answer this question, astronomers are racing to discover as many potentially hazardous asteroids (PHAs) as they can (see "Dodging an asteroid," *Astronomy*, December 2002). As of the end of 2003, they had found 691 asteroids greater than 0.6 mile (1 kilometer) in size — the threshold for global (instead of "merely" regional) destruction. Of these, 131 are classified as PHAs. In all, planetary scientists expect to find about 1,100 asteroids larger than 1 kilometer. If any are discovered on orbits that might collide with Earth one day, we may have to act to prevent the impact, although no one has more general ideas how to deal with one. In the meantime, however, astronomers seek to know the position and trajectory of each life-threatening space rock as accurately as possible.

Toutatis, at least, is nothing to be scared of, so get out your telescope and follow along. For most backyard observers, the best time will be the night of the 26th and, for those south of the equator, the 29th.



TOUTATIS DOESN'T LINGER for Northern Hemisphere observers. Plan to catch it as early in September as you can, when it lies at higher declinations and the Moon interferes less. ASTRONOMY: ROEN KELLY

What will I see?

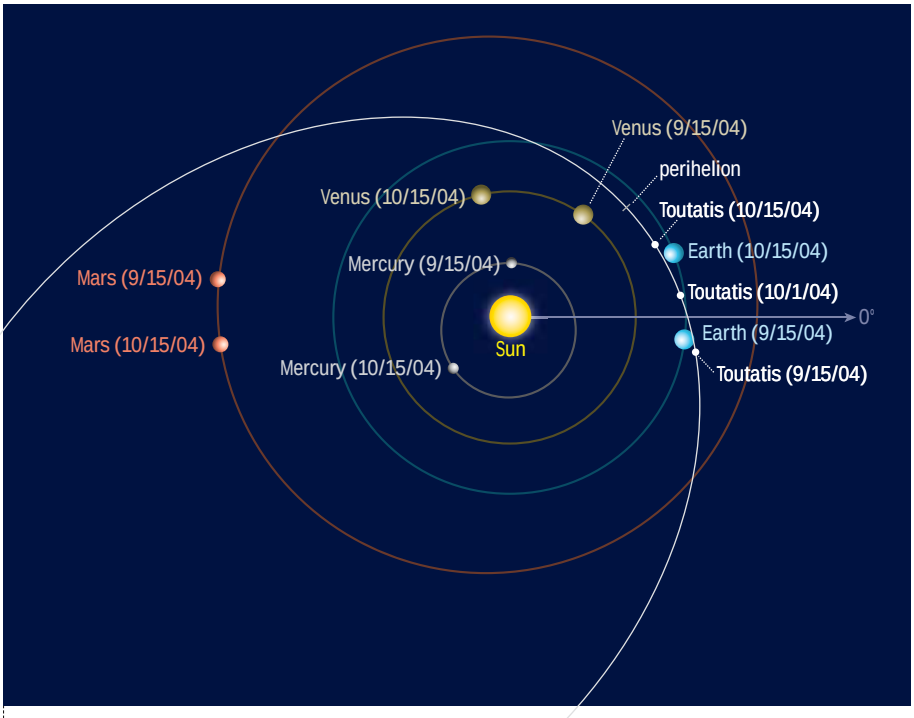
If you don't have a telescope, contact a local astronomy club or planetarium because they may schedule a time to watch it and will be glad to give you a peek. When you look in the eyepiece, don't be surprised to see just a faint white dot, through even a big telescope. Toutatis measures 3 by 1.5 miles (4.5 by 2.4 km), but this potato-shaped asteroid will pass about 960,000 miles (1.5 million km) away. It's not called "space" for nothing.

Observers who hunt asteroids regularly know that Toutatis's predicted brightness — 9th magnitude at best — is not overwhelming. In fact, with the Moon nearby in the sky, finding and following Toutatis will pose a challenge for anyone using a 6-inch scope under urban skies.

How fast will it be moving?

It depends on the night. Toutatis is like a line-drive baseball coming almost straight at us, so it doesn't seem to move much

Alister Ling *is a meteorologist for Environment Canada and a longtime backyard observer who explores the sky from home in Edmonton, Alberta.*



ORBITING THE SUN every 4 years in the virtually same plane as Earth guarantees that Toutatis makes many close approaches to our planet. The next such pass occurs in 2008, but it will be farther away — and offer less to see — than this year's. *ASTRONOMY:* ROEN KELLY

except when it gets close and is about to pass us by. On the 24th, it will cross a patch of sky the size of the Moon in 3 hours. By the 26th, it takes only 1.5 hours to go that distance, and by the 29th, Toutatis is traversing almost three Moon-diameters in just one hour! In physical terms, Toutatis is approaching us at 22,000 miles per hour (35,000 km/h).

Where do I look?

Find a site with a low horizon toward the south. Toutatis becomes a target for medium-size telescopes in mid-September near the bright star Delta (δ) Capricorni. This lies on the eastern (left) side of the Sea Goat. By the 27th, Toutatis is speeding southward through the far southern constellation Telescopium, visible to those near or south of the equator.

When an asteroid (or a comet) passes really close to Earth, its path on the sky differs depending on your observing site's location. In the case of Toutatis, this won't matter too much because the maximum offset, or parallax, occurs when it is visible only from the Southern Hemisphere.

Coincidentally, Toutatis starts off September 20 near globular star cluster M30. Because of the Moon's skyglow, M30 will appear smaller and fainter than usual, a pale gray cotton ball against a gray sky.

By Toutatis!

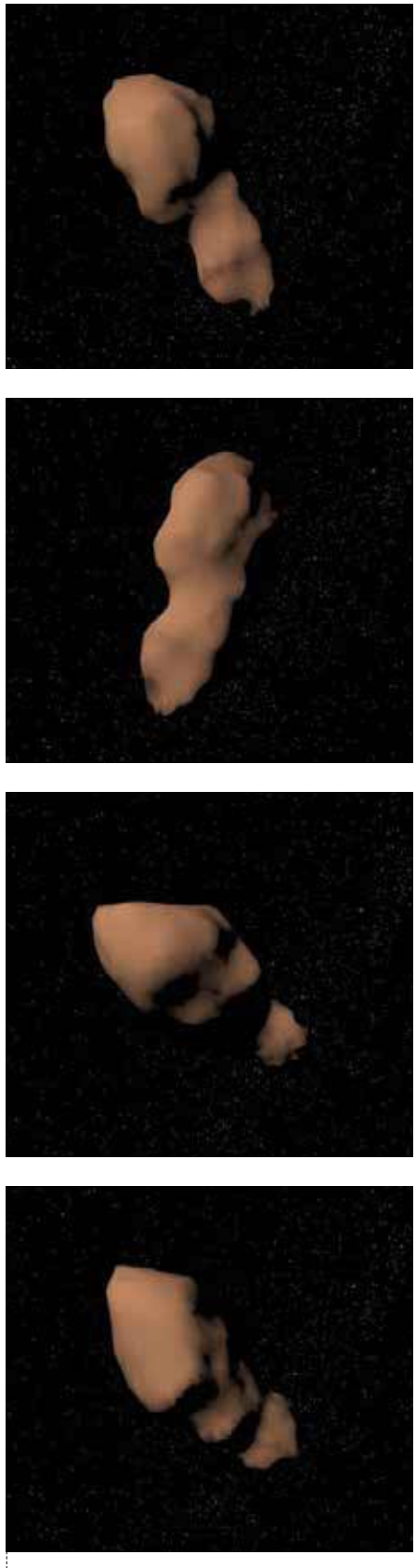
Before discovering the asteroid on January 4, 1989, French astronomer Christian Pollas (Observatoire de la Côte d'Azur) had begun naming the Earth-crossers he discovered after Celtic gods. He gave this particular rock the name of Toutatis, a deity often invoked by a tribe of Roman-defying Gauls in the popular French comic strip *Astérix*. (Interestingly, the only thing this indomitable tribe feared was that the sky would fall on their heads. Hmm. . .)

Next, please

After Toutatis shoots across the bow of spaceship Earth, no known asteroid will come closer to us until 2015. In four years Toutatis will return, but it will pass five times farther away, appearing fainter than Pluto does in backyard scopes.

The next reasonably bright asteroid to speed by is number 23187 in March 2006, but it will shine two magnitudes (a factor of six) fainter than Toutatis. Chances are, however, that another, new, close-approach asteroid will be discovered before then. To stay up-to-date on what's coming, check out the web sites listed in Resources on page 94.

To generate a Toutatis finder chart for your location, see www.astronomy.com/toc



TUMBLING LIKE A BAD FOOTBALL PASS, Toutatis has a complicated spin that combines rotations around two axes. Radar reveals that Toutatis may be a single object shaped by collisions — or perhaps two bodies that collided gently. WASHINGTON STATE UNIV., S. HUDSON/JPL, S. OSTRO

This inventory of 109 deep-sky treasures rivals Charles Messier's list in diversity and delight. /// TEXT BY MICHAEL E. BAKICH /// IMAGES BY ADAM BLOCK

The Caldwell Catalog

M11. M20. M31. Every amateur

astronomer recognizes these designations because this trio of deep-sky objects is found on the list of 18th-century comet hunter Charles Messier. M11 is the Wild Duck Cluster in Scutum; M20 is the Trifid Nebula in Sagittarius; and M31 is the Andromeda Galaxy. But what if the letter C replaces the M in front of those numbers? Would you recognize C11, C20, and C31? This trio of deep-sky objects is also well known, but perhaps not by these designations. The C stands for Caldwell, or more specifically, for Caldwell-Moore, the full surname of well-known British astronomy popularizer Sir Patrick Moore. When it came time to place an identifier by each of the numbered objects in his list, he couldn't use M for Moore because that letter was taken already (by Messier), so he chose the next best thing. Oh, and in case you're still wondering, C11 is the Bubble Nebula (NGC 7635) in Cassiopeia, C20 is the North America Nebula (NGC 7000) in Cygnus, and C31 is the Flaming Star Nebula (IC 405) in Auriga.

Moore devised his list in 1995 as a grand tour of celestial objects similar to Messier's. But where Messier's list is limited to objects that can be seen from the latitude of Paris (+48°51'), where Messier made his observations, Moore expanded his candidates to those ranging from high northern latitudes (+85°20') to low southern latitudes (–81°). This somewhat evens the score between Northern and Southern Hemisphere observers because 34 Caldwell objects are invisible from Paris's latitude, and five others never climb more than 3° above the southern horizon there. Included in this "invisible from Paris" group are standout objects such as the Tarantula Nebula (C103), the Coal Sack (C99), and the two finest globular clusters in the sky, 47 Tucanae (C106) and Omega Centauri (C80).

What was he thinking?

When the Caldwell Catalog made its initial appearance, some amateur astronomers railed at the audacity of Moore to name the list after himself:

"How dare he!"

"Many of these objects have names!"

My reaction was somewhat different: "Why didn't I think of that?" The *Bakich Catalog*. Now that has a nice ring, don't you think? Whatever your opinion is about it, the Caldwell Catalog contains 109 great deep-sky objects to observe.

Regarding object selection, relative to Messier's list, Moore slightly reduced the numbers in certain categories while increasing others. So the number of star clusters (both open and globular) and galaxies was reduced slightly, but the number of nebulae was increased. Only four planetary nebulae made Messier's list, but Moore placed 13 in the Caldwell Catalog. Likewise, Moore increased the number of bright nebulae from five to 12.

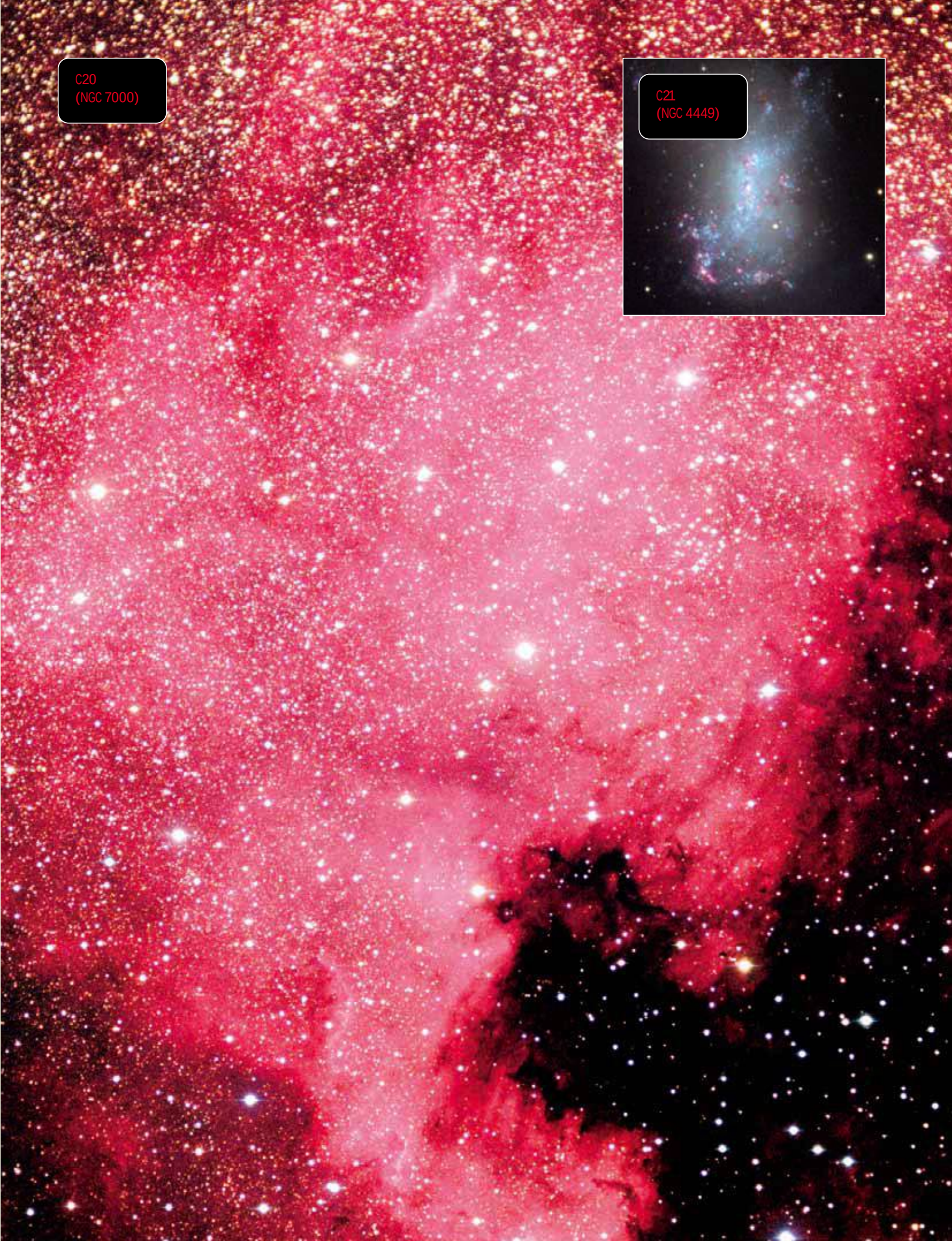
Moore also distributed his objects more widely across the sky. Sagittarius and Virgo, which have 15 and 11 Messier objects, respectively, have only one Caldwell object each. Perhaps Moore thought most of the great objects in those constellations were taken. In fact, you'll find more Messier objects per constellation than Caldwell objects. Cassiopeia, Centaurus, and Cygnus each contain six Caldwell objects — the most found in any constellation. Fifty of the 88 constellations contain Caldwell objects as opposed to 34 that contain Messier objects.

Moore numbered the objects in his catalog by declination. He started in the northernmost region of the sky with C1 (NGC 188, an open cluster in Cepheus) and ended near the South Celestial Pole with C109 (NGC 3195, a planetary nebula in Chamaeleon).

Moore's final stipulation was that each of the Caldwell objects be observable with a 4-inch telescope from a dark location. In fact, many of the objects on Moore's list are visible in binoculars, and some even can be seen with the unaided eye. Others are more difficult to see, and although they can be glimpsed through a 4-inch scope, a larger instrument brings out their subtle details.

Download a Caldwell object checklist and finder chart at www.astronomy.com/toc

Michael E. Bakich *is an associate editor of* Astronomy. Adam Block *facilitates the Advanced Observing Program at Kitt Peak National Observatory in Arizona.*


C20
(NGC 7000)
C21
(NGC 4449)

/// THE BAKICH TOP 10 CALDWELL OBJECTS

In the spirit of my favorite late night talk show host — and fellow amateur astronomer — David Letterman, I put together my Top-10 favorite Caldwell Objects. To help you find these and the rest of the Caldwell objects, visit *www.astronomy.com/toc* for a Caldwell checklist and maps showing the Caldwell object locations.

C #	NGC/IC	Const.	Type	R.A.	Dec.	Mag.	Size	Description
14	869/884	Per	OC	2h20m	57°08'	5.7	29' and 29'	Double Cluster
22	7662	And	PN	23h26m	42°33'	8.3	0.3'	Blue Snowball
53	3115	Sex	E6G	10h05m	–07°43'	8.9	8.1' x 2.8'	Spindle Galaxy
59	3242	Hya	PN	10h25m	–18°38'	7.8	0.3'	Ghost of Jupiter
63	7293	Aqr	PN	22h30m	–20°48'	7.3	13'	Helix Nebula
80	5139	Cen	GC	13h27m	–47°29'	3.5	36.3'	Omega Centauri
92	3372	Car	BN	10h44m	–59°52'	3	120' x 120'	Eta Car Nebula
94	4755	Cru	OC	12h54m	–60°20'	4.2	10'	Jewel Box
99	—	Cru	DN	12h53m	–63°00'	—	400' x 300'	Coal Sack
106	104	Tuc	GC	00h24m	–72°05'	3.8	30.9'	47 Tucanae

Key to object types: BN = Bright nebula GC = Globular cluster OC = Open cluster EG = Elliptical (type) galaxy
DN = Dark nebula PN = Planetary nebula

/// THE ADVANCED OBSERVING PROGRAM

Images like the ones in this story are among the finest taken by amateur astronomers, and now you can learn how to capture similar high-quality pictures. The Kitt Peak National Observatory Visitor Center offers an advanced observing program (AOP) geared toward amateur astronomers and others interested in using a large telescope with state-of-the-art instruments. No previous experience in astronomy is necessary. You can observe at the world's largest optical observatory under the superb sky of the southwestern United States. Guests who participate in this program are treated as visiting astronomers with complete access to the Visitor Center's considerable resources. Observe from an excellent site, dine with other astronomers, and above all, enjoy exploring the universe.

When you sign up for the AOP, the options available in the course of a night are quite diverse. The program's friendly staff will help you learn everything you might want to know. Create beautiful color CCD images of galactic nebulae; photograph star clusters; record video footage of the Moon and planets; take colorful, wide-field images of the night sky using film and a 35mm camera; perform a supernova or asteroid search; or just enjoy visual observing through large telescopes equipped with high-quality eyepieces.

If you are interested in this program, e-mail Adam Block at ablock@noao.edu, or call 520.318.8728. See full details at *www.noao.edu/outreach/aop*.

Astronomy sponsored tours to Egypt and South Africa for astronomy-enthusiasts to witness 2004's historic Venus transit /// *SOUTH AFRICA*: MICHAEL E. BAKICH; *EGYPT*: DAVE EICHER

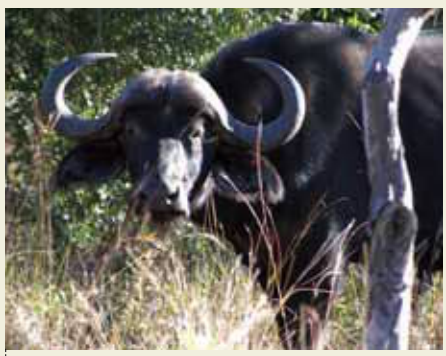
Venus transit trips

ENTABENI, SOUTH AFRICA — For

122 years, anyone mentioning a transit of Venus added, "last seen in 1882." Until June 8, 2004, that is, when, for more than 6 hours, a group of 35 travelers — and millions more lucky enough to be on Earth's sunlit side — watched the disk of Venus creep across the Sun's face.

A daylong flight followed by a 2-hour bus ride, then a short, dirt-road trek by Land Rover, delivered our tour group to the Entabeni Game Resort in South Africa June 6. During the 10-minute drive to the lodge, we saw zebra, baboons, and warthogs — a small portent of the exciting things to come.

You'd think after all the travel, we'd be looking for nothing more than a soft bed, but when asked to head out (immediately) for an afternoon game drive, almost every



HAVING A CAPE BUFFALO STARE AT YOU is a thrill on several levels. Although massive, these animals are amazingly difficult to locate in the wild. RICK SARRICA

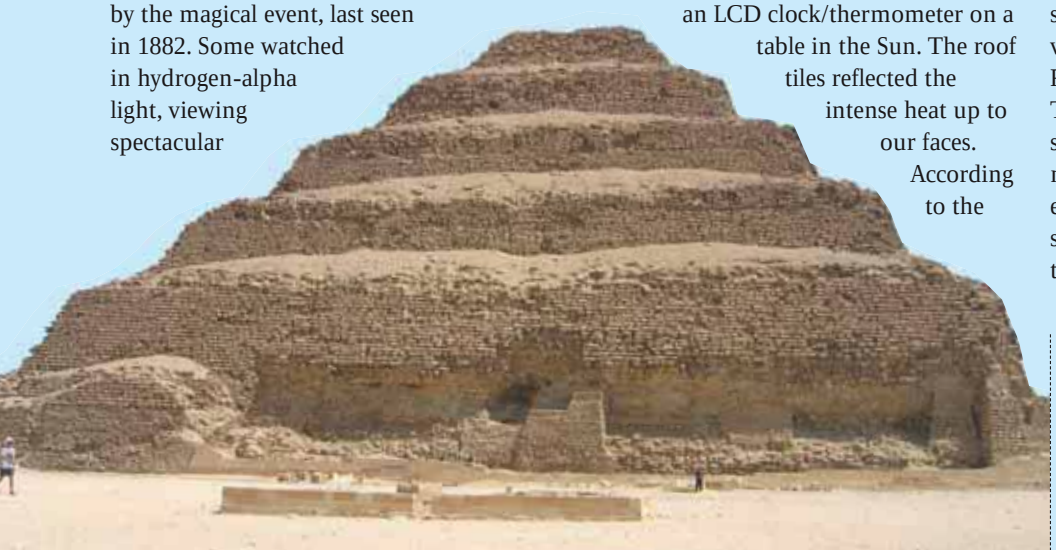
LUXOR, EGYPT — As the 122-year

countdown ticked to its conclusion, we all peered into eyepieces seeing just a golden globe of Sun, and then — wham! — a tiny black dot emerged onto the solar disk, signaling the start of the first transit of Venus seen by anyone now alive. It was a magic moment, as 68 of us huddled around telescopes and cameras set up atop the roof of the Luxor Sheraton Resort Hotel on the east bank of the Nile River. After shouts of joy rang out, minutes passed in relative silence, as one and all were transfixed by the magical event, last seen in 1882. Some watched in hydrogen-alpha light, viewing spectacular prominences, while others simply held eclipse glasses over their eyes.

The air temperature in Luxor on transit morning, June 8, was 117° Fahrenheit. *But it was a dry heat.* Someone placed an LCD clock/thermometer on a table in the Sun. The roof tiles reflected the intense heat up to our faces. According to the LCD, the temperature reached 138° F before its screen darkened and died.

Streams of perspiration could not dampen the excitement of *Astronomy*'s Egyptian transit party, an excursion organized by Vic and Jen Winter of Astronomical Tours, a Kansas City-based travel company. Once again, Vic and Jen planned an incredible excursion.

The trip began June 2 with flights into Cairo that afforded a wonderful aerial view of the Giza plateau and the great pyramids. We flew south to Aswan and saw the old and high dams before continuing southward to Abu Simbel, where we viewed the magnificent rock-cut temple of Ramesses II, constructed about 1250 B.C. The four seated figures of this Pharaoh stretch 69 feet high and are among the most impressive in Egypt. Amazingly, the entire temple was disassembled and reconstructed at a higher elevation in the 1960s to protect it from flooding caused by the



THE FIRST PYRAMID IN THE WORLD, Djoser's Step Pyramid at Saqqara — built by the architect Imhotep about 2630 B.C. — is one of more than 130 pyramids in Egypt. DAVE EICHER

VENUS TRANSITING THE SUN was a sight nobody had seen since 1882. Thankfully, the South African skies were clear and the weather was great. RICK SARRICA

STANDING IN THE HEAT on the rooftop of the Luxor Sheraton Resort Hotel, some of *Astronomy*'s transit viewers set up their telescopes and anticipate the beginning of the first Venus transit since 1882. Some viewed in hydrogen-alpha, some in white light; some made precise timings of the ingress and egress, while others simply stared in amazement as the black disk of Venus made its way across the Sun. DAVE EICHER

hand shot up. These "mini-safaris" continued at a rate of two a day throughout our four-day stay at Entabeni.

We saw a variety of animals — giraffes, monkeys, wildebeest, impala (and many other kinds of antelope), warthogs, cape buffalo, bush babies, aardvarks, elephants, jackals, and rhinoceros (my personal favorite). But the most exciting animal sighting by far was the lions. On one evening game drive, our ranger got a call (via CB radio) to let him know lions had been spotted. We were all the way across the lion habitat when he got the call.

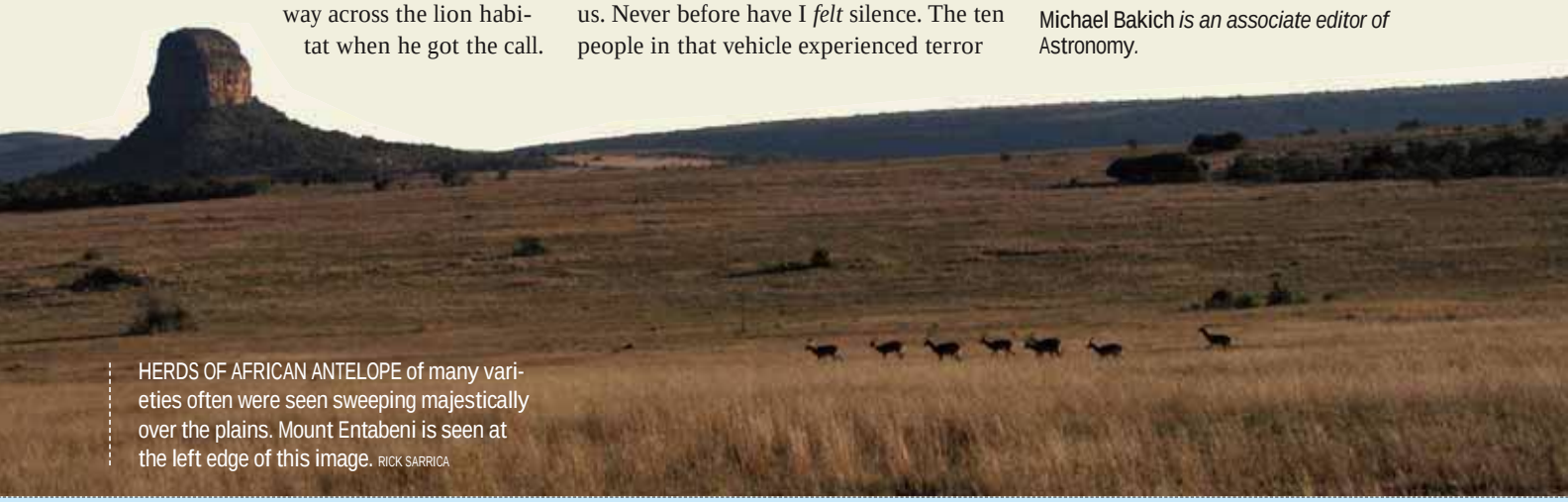
For the next several minutes, we sped through the landscape on a truly wild ride. Upon our arrival, we saw two female lions in the grass stalking a herd of wildebeest. We watched them and could hear a male lion roaring in the distance behind us.

When we turned around to head back to the lodge, the jeep leaving the location in front of us had the male lion in its spotlight. So our ranger parked our Land Rover and we waited. This lion — the fourth largest in Africa, according to officials — passed no more than a meter from us. Never before have I *felt* silence. The ten people in that vehicle experienced terror and wonder in the same moment, and none of us will ever forget it.

The location

The Entabeni Game Lodge lies at an elevation of 5,000 feet (1,524 meters) and is at latitude –25°, so not only did we have a first-class view of the transit June 8, but we also enjoyed the spectacular wonders of the southern sky. Let that latitude sink in for a second. From our location, southern sky objects were almost 50° higher than

Michael Bakich *is an associate editor of* Astronomy.



HERDS OF AFRICAN ANTELOPE of many varieties often were seen sweeping majestically over the plains. Mount Entabeni is seen at the left edge of this image. RICK SARRICA

construction of the Aswan High Dam and creation of Lake Nasser.

Back in Aswan, we were treated to a felucca sailboat ride around Elephantine Island and to new Philae Island, where the Greco-Roman Temple of Isis was rebuilt, also to avoid flooding from the dam project. The sound and light show at Philae emblazoned the remnants which date to between about 700 B.C. and about A.D. 800.

After the show, we boarded the MS *Serenade* — one of several hundred Nile cruise ships that regularly make their way up and down the river — for a journey northward. At Edfu, we went ashore to participate in a wild horse-cart ride, and came together to put on a shipboard play — our variation of "Death on the Nile."

Our group had not anticipated the spectacular scale and amazing state of preservation at the temples of Karnak and Luxor, once the religious and governmental center of the unified Upper and Lower Egypt. The whole east bank of Thebes was built up around 1550 B.C., and here, names such as Hatshepsut, Tutankhamun, and Ramesses II entered the stage as among the greatest of Egypt's legends. The avenue of sphinxes between Karnak and Luxor exemplified the great scale of ancient Egyptian architecture.

Dave Eicher *is editor of* Astronomy.

FROM THEIR ROOMS at the Luxor Sheraton Resort Hotel, *Astronomy*'s travelers could see across the Nile River to ancient Thebes on the west bank, with the mountains that surround the Valley of the Kings, including Tutankhamun's tomb, in the background. DAVE EICHER

Back to antiquity

Following transit day, after evacuating from the scalding roof, we carried on our pursuit of ancient Egypt. Fortunately, we had two expert Egyptologists with us,

SOLAR PROJECTION was a good way for many people to observe the Sun and Venus. A Sunspotter from Learning Technologies, Inc., allowed easy viewing. RICK SARRICA

those seen at the most southerly star party in the contiguous United States (the Winter Star Party in the Florida Keys). Oh, and in six nights during our prime observing hours (before moonrise), not a single cloud intruded.

Observing highlights included the two finest globular clusters in the sky, Omega Centauri (NGC 5139) and 47 Tucanae (NGC 104), the radio galaxy Centaurus A (NGC 5128), the Eta Carinae Nebula (NGC 3372), and the Jewel Box Cluster (NGC 4755).

In addition to deep-sky treats, both of the recently heralded comets, C/2002 T7 (LINEAR) and C/2001 Q4 (NEAT), were visible to the naked eye in the early evenings. And each night at 11 o'clock local time, Scorpius and the center of our Milky Way were overhead.

The transit

On transit day, we arose at dawn. An hour before first contact — the initial meeting of Venus and the Sun — all equipment was poised and ready. Roy Mayhugh, of Mayhugh Travel, *Astronomy*'s partner for this tour, brought an impressive array of equipment to capture close-up views of the historic event: 4-inch Tele Vue and 6-inch Astro-Physics refractors, 11-inch Celestron and 12-inch Meade Schmidt-Cassegrain telescopes, and — for those with "aperture fever" — a 25-inch Obsession Newtonian reflector.

Several members of our group brought telescopes with both visual light and hydrogen-alpha (Hα) filters. The latter filters permit light of only a specific wavelength — Hα light — to pass through to the eye. Five previous transits have been observed (in 1639, 1761, 1769, 1874, and 1882), but this was the first to be observed through Hα filters.

The views through the Hα scopes were the most popular, and not just because of the show Venus was putting on. Through an Hα filter, prominences are visible along the Sun's edge, and bright, white solar flares can be seen on its disk. Several of

CREATURES LIKE THIS WARTHOG are among the reasons people visit Africa. The transit, however, reduced animal spotting to "important but not essential." RICK SARRICA

Hossam and Tarek, who made understanding what we were seeing a delight. The trip came to a crescendo when we saw the Valley of the Kings and climbed through several tombs, including that of Tutankhamun.

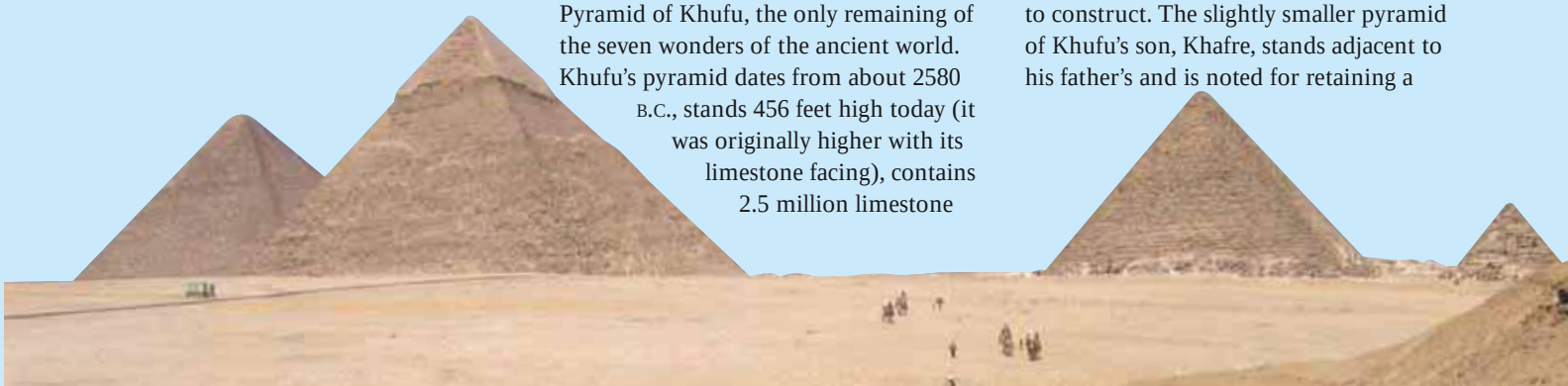
Tourists at every historical site we visited were protected by local police or by tourist police and the Egyptian army, all of whom were openly armed with automatic rifles and machine guns. Following the November 1997 massacre of 58 tourists at Queen Hatshepsut's Temple by an Egyptian Islamic extremist group, the Egyptian government has taken the issue of security extraordinarily seriously.

We switched gears by driving past the City of the Dead to the Citadel in Old Cairo, where we explored the Mosque of Mohammed Ali, a sacred site. At the Church of Saints Sergius and Bacchus, we saw the site at which, according to tradition, Mary, Joseph, and the infant Jesus rested on their journey into Egypt following their escape from King Herod.

On June 10, we returned to ancient Egypt with a journey southward to Saqqara, where we reveled in the beauty of Djoser's Step Pyramid — the first of its kind when it was constructed about 2630 B.C. — and his funerary complex.

June 11 found us touring the greatest of all the pyramids at Giza: the Great Pyramid of Khufu, the only remaining of the seven wonders of the ancient world. Khufu's pyramid dates from about 2580 B.C., stands 456 feet high today (it was originally higher with its limestone facing), contains 2.5 million limestone blocks, each weighing about 2.5 tons, and took about 25,000 workers some 23 years to construct. The slightly smaller pyramid of Khufu's son, Khafre, stands adjacent to his father's and is noted for retaining a

BRILLIANT COLORS ADORN TEMPLES such as the Temple of Karnak. Much later, when Christians used the building as shelter, they eradicated the Pharaoh, but not the gods.



THE GIZA PYRAMIDS tower over the surrounding desert; they were built by, (left to right) Khufu, Khafre, and Menkaure; they are the only remaining example of the seven wonders of the ancient world. DAVE EICHER

"DON'T STAND OR MAKE ANY SUDDEN MOVEMENTS" was the advice we received from our park ranger when we encountered potentially dangerous animals on game drives. In all, we saw four of Africa's "Big Five" — lions, elephants, cape buffalo, and rhinoceros, missing only the elusive leopard. RICK SARRICA

SETUP FOR THE TRANSIT was completed well before the start of the event. Here, Shad Nygren (seated) and Jim Uber enjoy a momentary break prior to sunrise. RICK SARRICA

both features were visible clearly throughout the transit.

Visually, Venus resembled a large, perfectly round sunspot. It was seen easily through the telescopes at all magnifications. It also was easy to spot with the naked eye — properly protected through a #14 welder's glass or with optical Mylar. You might think an event lasting more than 6 hours would get boring, but interest remained active throughout. Group

portion of the gleaming white limestone facing on its cap. The third pyramid, much smaller than the other two, was built for Menkaure, Khufu's grandson.

No trip to Egypt would be complete without a journey to the Egyptian Museum in Cairo, where we were stunned to see thousands of treasures including the grave goods of Tutankhamun. Nor would such a trip be complete without a visit to the Cairo bazaar, where haggling is the only way to make a transaction at any of the dazzling array of hundreds of shops and vendors on site.

Following a farewell dinner, we all reflected on the main reason we had come: the transit of Venus. Ken Wilson of Richmond, Virginia, commented on the intense heat we all endured throughout our stay in Egypt. "I couldn't help but think it was appropriate," he said, "because we were observing the disk of the planet with the hottest surface temperature in the solar system pass in front of the hottest object in the solar system. But this didn't make me feel any cooler!"

And I couldn't help thinking how amazing it was to view the Sun in a land where the Sun, in ancient times, was the god Re. By careful alignment of the pyramids and temples, the Pharaohs — the children of Re — were to be taken up into the sky after their deaths to be reborn again as stars among the gods.

How appropriate, I thought, that the stars and the planets met in alignment so perfectly that sunny day along the Nile. A

See more images from Michael and Dave's trips at www.astronomy.com/toc

THE GREAT SPHINX guards the pyramids at Giza. The Sphinx was most likely created at the time of Khafre's pyramid, about 2570 B.C. DAVE EICHER

members realized they were witnessing a sky event *nobody alive* had seen, and not one of *us* will forget.

Post-transit adventures

After departing the Entabeni Game Resort June 10, we headed to the Mt. Grace Country Spa, in the Magaliesburg Mountains (an hour from Johannesburg), for the last two days of our stay. While at the spa, we toured the nearby Cradle of Humankind, the world's richest site for early hominid fossils.

On our final day in Africa, we visited the Hartebeesthoek Radio Astronomy Observatory.

Roy and Bonnie Mayhugh, our travel providers, deserve special thanks for their preparation and graciousness throughout the trip. Our South African guide, Mr. Terry Leaver, proved to be a wonderful resource, able to discuss and explain a wide variety of topics. The weather was perfect, the equipment performed flawlessly, and the event exemplified sublime celestial geometry to all who witnessed it.

Next stop — the 2005 eclipse from the South Pacific. A

THE HARTEBEESTHOEK RADIO ASTRONOMY OBSERVATORY originally was used to monitor the Apollo space flights. The observatory is one of South Africa's finest astronomy facilities. The 26-meter radio telescope formed the backdrop for our "Venus Transit" group photo. MICHAEL E. BAKICH

KARNAK'S FAMOUS OBELISKS mark the accomplishments of Tuthmosis I and Hatshepsut, who added to the temples of Karnak and Luxor at a furious pace. DAVE EICHER

HATSHEPSUT'S TEMPLE on the west bank at Thebes appears as perhaps the most beautiful rock-hewn building of antiquity. Queen Hatshepsut ruled as a Pharaoh about 1458–1443 B.C.

THE TEMPLE OF RAMESSES II at Abu Simbel warned ancient travelers to respect the Pharaoh's authority. In the 1960s, it was rebuilt at higher elevation when Lake Nasser was created. DAVE EICHER

If you're looking for optical quality in a small package, consider one of these fine telescopes. /// BY STEVE EDBERG

The Maksutov revolution

Among the telescopes available today, the Maksutov-Cassegrain (or Maksutov, for short) ranks fourth in popularity. Russian astronomer Dmitri Maksutov (1896–1964) invented the optical design in 1944. Dutch astronomer A. Bouwers, who may have preceded Maksutov, independently developed the design. What we now call the Maksutov telescope is a hybrid optical system using both mirrors and a lens to produce images at the focus. Such systems are called catadioptric. The more common Schmidt-Cassegrain telescope is also a catadioptric system.

The primary difference between the two is the corrector lens found on the "sky" end of the telescopes. Whereas a Schmidt-Cassegrain uses a thin lens shaped with a complex curve, the Maksutov lens is thick and has matching spherical curves ground into it. The lens is a thick shell of glass, which conveniently minimizes spherical aberration and provides sharp images. The corrector's curvature is oriented concave out. This means the lens would hold rain if the telescope were left outdoors pointed at the sky. The secondary mirror often is coated directly on the inner surface of the corrector lens. Schmidt-Cassegrain telescopes employ a cell to house the secondary mirror. The cell usually protrudes through a predrilled hole in the corrector.

With its thicker corrector, a Maksutov is a bit heavier than a Schmidt-Cassegrain of the same aperture. Optically, Maksutovs are easier to make, requiring only three spherical surfaces to be ground and polished. The secondary mirrors of Maksutovs are usually smaller than those on Schmidt-Cassegrains because their slower (larger f number) optics don't require as large a secondary mirror. All other qualities being equal, a smaller secondary mirror means that the viewed images will have higher contrast than through telescopes with larger secondary mirrors. Contrast in the viewed image depends heavily on scattered light, and a smaller secondary scatters less light.

One concern with Maksutovs can be their optical alignment, or "collimation." The corrector lens and the secondary mirror attached to it must be aligned perfectly with the primary mirror or the final image will be degraded. Collimation is not easily adjusted so make sure the out-of-focus star images in your Mak show nicely centered donuts at the center of the field of view.

Astronomy evaluated Maksutov telescopes from Celestron, LOMO, Meade, Orion, and Questar. These telescopes were tested with any eyepieces supplied with them and also with some of my favorite eyepieces. A few of the telescopes came with mounts (which were not evaluated) while others were supplied as only optical tube assemblies. Mounts for this group can be obtained from the telescope source or other vendors. All knobs and flip controls on these telescopes are easy to manipulate, even with light gloves on and even on the darkest night.

Steve Edberg *has a variety of telescopes so he can choose the right one for every occasion. His wife is not amused.*

Astele™ 133.5
$1,099.95
LOMO America, Inc.
15 East Palatine Road, Unit 104
Prospect Heights, IL 60070
[t] 847.215.8800
[w] www.lomopic.com/telescopesFrames.html

LOMO America™ imports the Russian-made Astele 133.5 (the aperture in millimeters, equal to 5.3 inches) Maksutov telescope, as well as other sizes. This telescope operates at a focal ratio of 10.13, close to that of many Schmidt-Cassegrains. The faster f-ratio requires it to have a larger secondary mirror than other brands of Maksutovs with similar apertures. Its focal length is 1352mm. A 25mm Plössl eyepiece (54x) is included, along with a prism star diagonal, a T-adapter for a camera (you'll have to provide your own T-ring), and a dew cap, making for a complete package. The finder is a generous 8x40 right-angle system. I liked the tripod-mounting bracket on the base of the telescope. Although it had only one hole for a tripod, it has a dovetail cross-section that allows easy balancing on a mount specifically set up to receive the bracket. The telescope is boxed well but it does not come with a case.

ETX-125
$995
Meade Instruments Corporation
6001 Oak Canyon
Irvine, CA 92618
[t] 800.626.3233
[w] www.meade.com

Meade Instruments offers Maksutov telescopes in several sizes. I previously reviewed Meade's ETX-90, so for this roundup I report on the 5-inch f/15 ETX-125EC. This telescope comes on a dedicated two-tined fork mount. The package includes a 26mm Plössl eyepiece, a small, right-angle finder, a tripod, and a go-to hand controller.

The telescope has two exit ports for its images. The one at right angles to the optical axis is normally used with eyepieces for visual observing. The other exit port, at the back of the scope, is used with a camera for a straight-through configuration (with accessories required). Switching between optical configurations is easy — just turn a knob and refocus. Note that the eyepiece can end up in awkward viewing positions when the telescope and mount are used in an equatorial configuration and when you are viewing objects with high declinations.

NexStar 4
$479
Celestron
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

Celestron's NexStar 4 is the successor to its C90 Maksutov, which was available in a variety of forms. This new telescope comes mounted on a single-tined "fork" with computer control.

The optical tube assembly has an aperture of 4" and is f/13. The package comes with 25mm and 10mm eyepieces and a red-dot rifle-type pointer/finder.

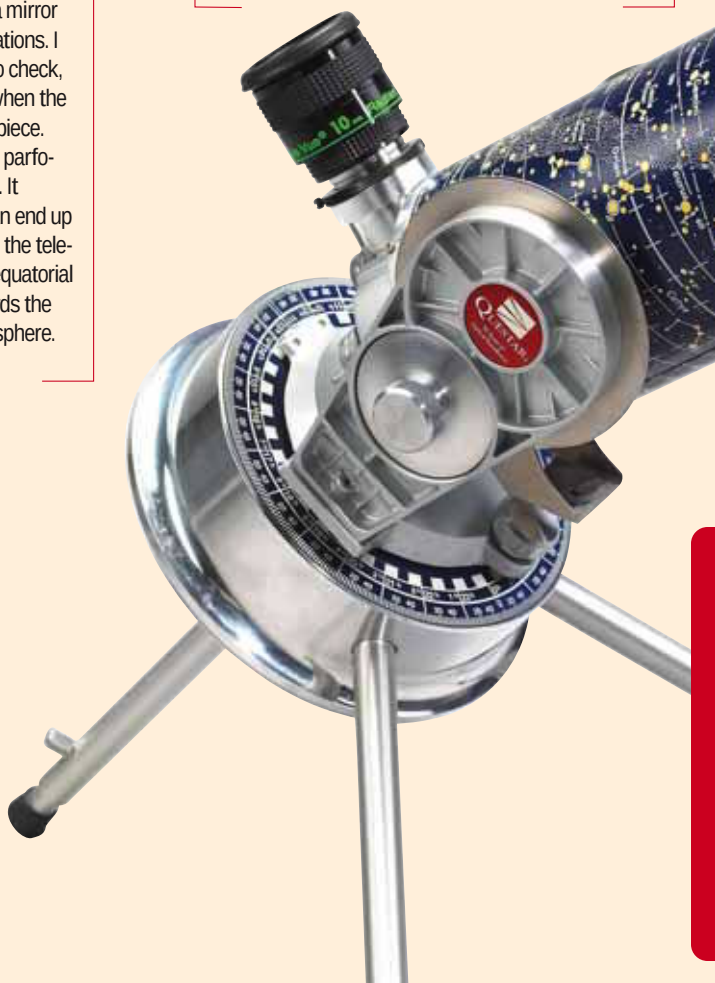
The telescope has two exit ports. The one at right angles to the optical axis is normally used with eyepieces, while a camera is used in the straight-through configuration (with accessories required). Turning a large, rubber coated knob slides a mirror back and forth to switch between configurations. I didn't have the photographic accessories to check, but I expect refocusing is also necessary when the switch is made between camera and eyepiece. You might want to get or make a tube to parfocalize the photographic and visual foci. It should be noted that the eyepiece can end up in awkward viewing positions when the telescope and mount are used in an equatorial configuration with viewing towards the high declinations of your hemisphere.

Questar 3.5"
$4,050
Questar Corporation
6204 Ingham Road
New Hope, PA 18938
[t] 800.247.9607
[w] www.questar-corp.com

The Questar 3.5" is a gem of fine machining and optical perfection. It comes as a complete package on a two-tined fork mount and with short legs that permit tabletop use as an equatorial telescope. (It can also be tripod-mounted, alt-az, or polar/equatorial.) The package includes screw-in 16mm (81x) and 24mm (54x) eyepieces, a finder, and solar filters for the main telescope (sub-aperture) and finder all packaged in a leather carrying case.

The telescope has two optical exit ports. The one at right angles to the optical axis is used with eyepieces while a camera and other visual accessories can be used "straight-through." Switching configurations is easy — just turn a knob.

But more switching is available on the rear of this telescope. While eyepieces can be exchanged in the usual manner, you can also turn a knob to bring an internal 1.5x Barlow lens into position. The finder works the same way. Turning a knob moves a prism in the main telescope out of the way. You now have a right-angle finder view through the eyepiece. The Questar 3.5" uses a separate, small objective lens and mirror to bring the finder's view of the sky into the light path.

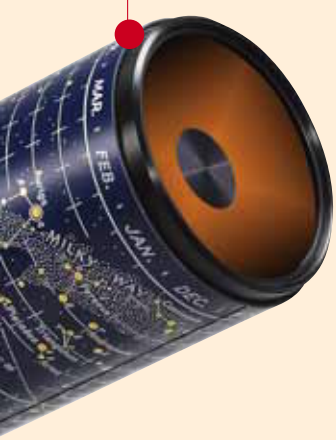


Apex 127
$399
Orion Telescopes and Binoculars
P.O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

Orion's Apex 127mm Maksutov-Cassegrain optical tube assembly appears to be the same as its StarMax 127 that comes with a German equatorial mount (and at a lower price). Orion also markets the Apex line in 90mm (3.6-inch) and 102mm (4-inch) apertures.

The Apex 127mm has a 5-inch aperture, a focal length of 1,540mm, and a photographic speed of f/12.1. It comes with a 6x26 straight-through, erect-image, achromatic finder scope, a 45° correct-image prism diagonal, and a 1¼", 25mm Plössl eyepiece, which provides a magnification of 62x. All this is packaged in a nice, roomy, padded, nylon-polyester case with pockets for accessories.

The Apex 127 is connected easily to any telescope mount or sturdy camera tripod thanks to a built-in 1/4"-20 adapter plate. T-threads on the eyepiece adapter allow you to attach a 35mm camera body (with optional T-ring) to the telescope for prime focus astrophotography.



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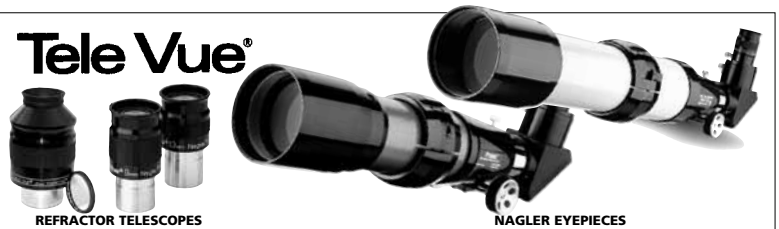

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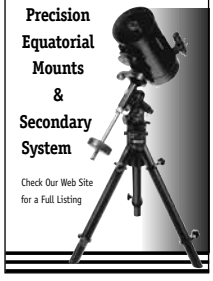

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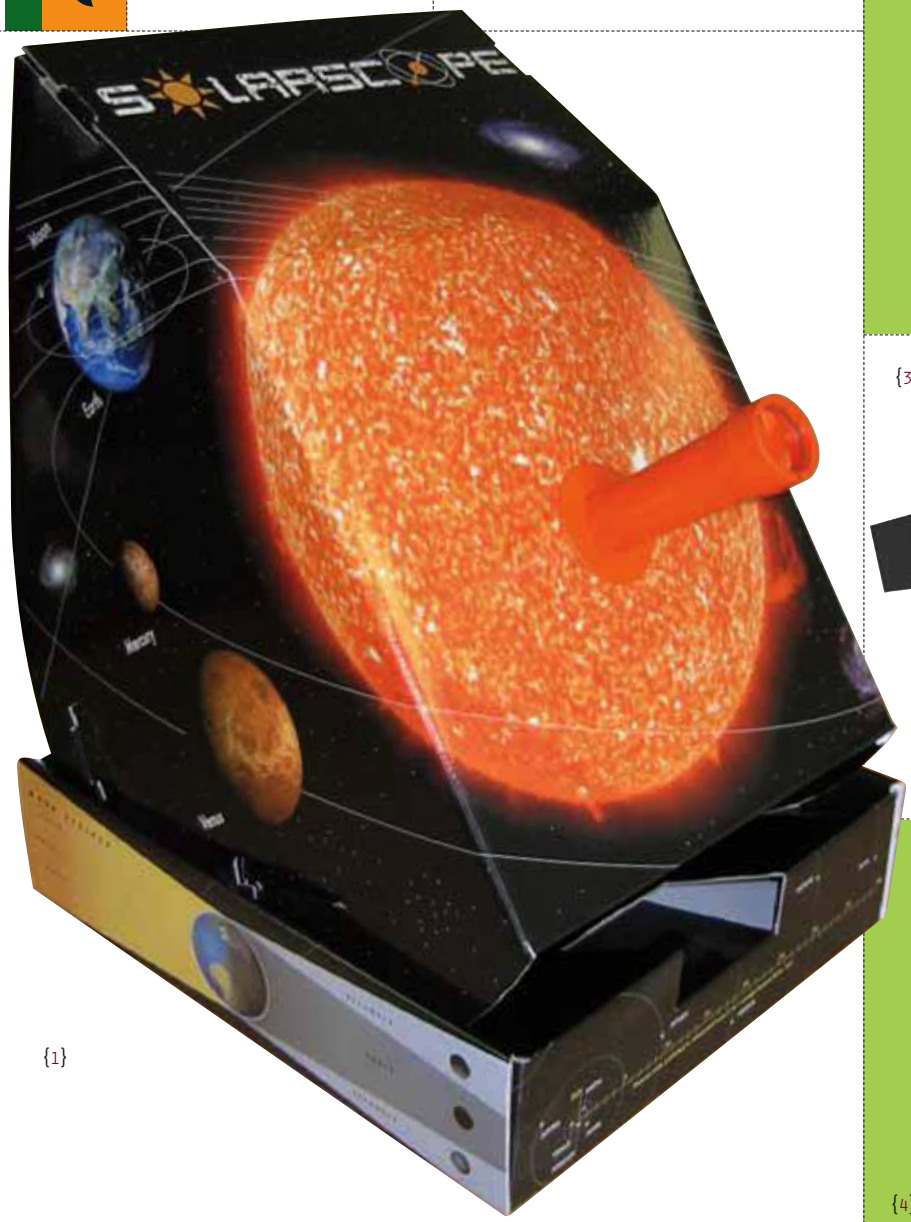

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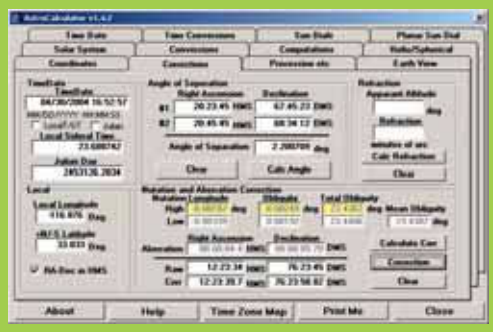

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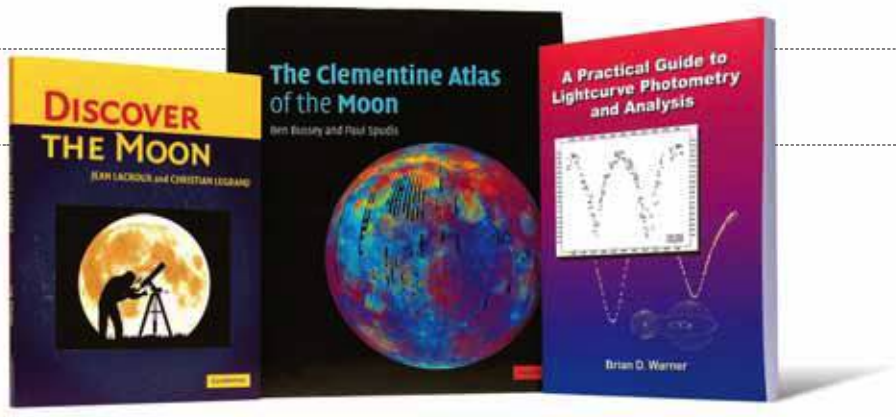

Discover the Moon

Jean Lacroux and Christian Legrand, 143 pages, Cambridge University Press, New York, 2004; ISBN 0–521–53555–7; paperback, $16.

The Clementine Atlas of the Moon

Ben Bussey and Paul Spudis, 316 pages, Cambridge University Press, New York, 2004; ISBN 0–521–81528–2; hardcover, $80.

These two Moon books aim at somewhat different audiences, but both will appeal to most lunar observers.

To begin with the Clementine work, the authors provide an atlas of the entire Moon in 144 paired plates. Each plate pair combines a visual wavelength photo mosaic from the Clementine mission with a shaded relief map, fully annotated with feature names. Each plate covers 16° of latitude and 20° to 35° of longitude (higher latitudes have greater coverage). The atlas includes a full gazetteer.

If the Clementine atlas works best as an indoor reference, *Discover the Moon* is one you want at the telescope. It is nearly perfect for beginners because it provides a night-by-night tour of the lunar nearside as seen in small and medium telescopes. By the time you've worked through its 14-evening program, you'll be familiar with the Moon's main features.

The brief chapters on choosing and using a telescope and taking lunar photographs fall a bit short because the topics are too intricate to deal with in the space at hand. (Some diagrams also still have labels in the book's original French.)

However, this book is highly observer-friendly. All images have south up and each is printed twice, one as a mirror image to match the view through a telescope with a star diagonal. Terrific idea!

— ROBERT BURNHAM *is a senior editor of* Astronomy *and a longtime moonwatcher.*

A Practical Guide to Lightcurve Photometry and Analysis

Brian D. Warner, 266 pages, Bdw Publishing, Colorado Springs, Colorado, 2003; ISBN 0–9743849–0–9; paperback, $30.

This book's author (same name as me, but no relation!) is one of the world's leading amateur astronomers in the area of CCD photometry. His book combines lots of experience with clear instructions. Any owner of a small telescope and CCD photometer will feel encouraged to try to make such professional scientific contributions as the author's.

He covers practical aspects of CCD photometry, almost without equations, because they are incorporated into the software that runs the photometer system. Warner distills years of experience into a readable, even laid-back, text that should present no barriers to the novice and will be valuable even to veterans.

The book concentrates largely on light curves of asteroids, but it applies equally to variable stars. It has extensive procedural details supplemented by appendices with examples and with finding charts and magnitudes for photometric standard stars. The latter is a great asset.

The only weak area is the glossary. For example, the definition of "parallax" applies only to the Moon, not in general. The definition of "center of mass" is incorrect. The description of the various kinds of novae is confusing. And the definition of "alias" is too restrictive — the text actually deals with aliasing more satisfactorily.

But this is altogether a delightful book, which I hope will inspire all owners of small telescopes and CCD cameras.

— BRIAN WARNER *is at the University of Cape Town (South Africa), where his research centers on high-speed photometry.*

Blowing Bubbles in the Cosmos

T. W. Hartquist, J. E. Dyson, D. P. Ruffle, 167 pages, Oxford University Press, New York, 2004; ISBN 0–19–513054–5; hardcover, $45.

Breezes, bangs, and blowouts are facts of life in the universe. All kinds of objects routinely throw off material that winds up in the interstellar (and intergalactic) environment. This is a good thing because the Sun and planets formed out of such stellar castoffs — without them, we wouldn't exist. Intended for the interested lay reader, this book by three research astronomers explores the role that flows of material play in the evolution of the universe at all scales. Outflows affect the rate at which stars are born as well as how they live and die. Outflows also control how galaxies (individually and in groups) change and evolve. What at first seems like the flimsiest of subject matter ends up being the key to unlocking many astrophysical mysteries.

Exploring the Starry Sky

Robert Burnham and Wil Tirion, 24 pages, Cambridge University Press, New York, 2003; ISBN 0–521–80251–2; paperback, $12.

The night sky is a part of the natural world that remains a mystery to many people, even to those who are otherwise alert to nature. This book has eight naked-eye sky charts, two for each season, that aim to introduce beginning skywatchers to the main constellations. Each sky map is accompanied by a zoomed-in map showing a particular region in detail. The text is low-key and friendly. Appendices list solar and lunar eclipses, and the locations of planets along the ecliptic, through 2006.

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10.05.04–10.09.04

The Enchanted Skies Star Party,

well-known for excellent dark skies and outstanding daytime programs for the past decade, has expanded to a five-day schedule to accommodate new hands-on workshops and a full night of observing. ❨ Held annually in Soccoro,

THE VERY LARGE ARRAY, seen here at sunset, will be open to Enchanted Skies Star Party attendees for guided, behind-the-scenes tours of its facilities. LEWIS McCOOL

New Mexico, this line-up features a series of workshops on CCD imaging and bringing astronomy to local communities through educational outreach. This series is presented by the Astronomical Society of the Pacific.

The highlight will be a night atop South Baldy Peak, a 10,700-foot mountain that soon will host the Magdalena Ridge Observatory. Bring your scopes to this site and enjoy the high-quality observing conditions that attracted the builders of a $40-million optical interferometer.

For more information, e-mail chamber@socorro-nm.com; web site, *www.socorro-nm.com/starparty.*

10.02.04

Federation of Astronomy Societies Convention

Institute of Astronomy, Cambridge University, Cambridge, England. The primary purpose of this event will be astronomical lectures. The theatre holds 180 people, so be sure to reserve seats before the event. For more information visit *www.fedastro.org.uk.*

10.13.04–10.17.04

Peach State Star Gaze

White Water Express High Adventure Camp, Duck Town, Tennessee. Just across the Georgia state line, this event will feature speakers, vendors, workshops, and door prizes. For more information, e-mail pssg@atlantaastronomy.org; web site, *atlantaastronomy.org.*

10.14.04–10.17.04

Southern New Mexico Star Party

City of Rocks State Park, Faywood, New Mexico. Hosted by the National Public Observatory (NPO), this biannual event is held at a scenic state park with an elevation of over 5,000 feet, ensuring dark skies. For more information, contact NPO president John Gilkison at P. O. Box 19,

Radium Springs, NM, 88054; phone, 505.527.8386; e-mail, jgilkiso@zianet.com; web site, *astronomy-national-public-observatory.org*.

10.15.04–10.16.04

All Arizona Star Party

Farnsworth Ranch, Arizona City, Arizona. Located midway between Phoenix and Tucson, this dark-sky site provides a great refuge for astronomers from both cities. For more information, contact Howard Israel at 480.893.0013; web site, *www.eastvalleyastronomy.org*.

10.15.04–10.17.04

Custer Institute Astronomy Jamboree

Custer Institute, Southold, New York. An annual event for more than a quarter century, the Jamboree features observing, workshops, and speakers, including NASA researcher Rich Terrile and Dava Sobel, author of *Galileo's Daughter*. For more information, call 631.765.2626.

10.15.04–10.16.04

Death Valley Star Party

The Furnace Creek Inn and Ranch Resort, Death Valley, California. The weekend will include lectures, observing presentations, and solar viewing. For more information, call Phyllis Nefsky at 760.786.3353.

10.15.04–10.17.04

Rencontres Astronomiques Neuchateloises - Star Party of Western Switzerland

Tite de Ran, Neuchtel, Switzerland. This informal get-together of regional astronomical groups offers observing, workshops, lectures, contests, and a large astronomical flea market. For more information, e-mail ran@net2000.ch; web site, *www.teleskoptreffen.ch/ran*.

10.15.04–10.17.04

Stella-Della-Valley

Camp Onas, Ottsville, Pennsylvania. This 18th annual gathering is sponsored by the Bucks-Mont Astronomical Association. Activities include guest speakers, a flea market, demonstrations, and observing. For more information, call Ed Radomski at 215.822.8312; e-mail, ejrado@tradenet.net; web site, *www.bma2.org/sdv.html*.

10.16.04

Virginia Association of Astronomical Societies Convention

Charlottesville, Virginia. The event was founded in 1975 with a gathering between the Richmond Astronomical Society and original Norfolk Astronomical Society. The day features observing and speakers, including Steven Dick, NASA's chief historian. For more information, visit *www.vaas.org*.

10.23.04

Colorado Astronomy Day

Denver Museum of Nature and Science, Denver. The Denver Astronomical Society, University of Denver, and Chamberlin Observatory will host a variety of astronomical activities for all ages. There will be observing at night with an array of scopes, including an Alvan Clark 20-inch refractor. For more information, contact Steve Solon at 303.871.5172; web site, *www.thedas.org*.

11.07.04–11.14.04

Chiefland Star Party

Chiefland Astronomy Village, near Chiefland, Florida. This star party allows non-members to observe the dark skies and participate in the activities that Chiefland community members enjoy year-round. Don't hesitate, all registration entries must be postmarked by October 1. For more information, e-mail Joe Mize at jmize@swic.net, web site, *www.c-av.com*. A

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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RESOURCES

Learn more about this issue's topics:

BEYOND HUBBLE

ARTICLES — Although astronomers will see a need to replace or even surpass the capabilities of the Hubble Space Telescope eventually, that doesn't mean we should forget about the revolutionary science and stunning images it has returned. A recap of the mission, including the contributions from the telescope's Wide Field and Planetary Camera 2, can be found in "Hubble's dazzling decade" by Richard Talcott (*Astronomy*, December 2003).

An in-depth look at one of Hubble's latest, and arguably, greatest observations — the million-second exposure known as the Hubble Ultra Deep Field — appeared in "To the cosmic edge" by Frank Sietzen, Jr. (*Astronomy*, July 2004).

WEB — Although the Very Large Space Telescope remains in the earliest concept stages, NASA already has made great progress on the James Webb Space Telescope. For details on what JWST will do, visit *www.jwst.nasa.gov*.

CASSINI REACHES SATURN

ARTICLES — For details on Cassini's flyby of Saturn's captured moon Phoebe, as well as the closest images of this moon ever taken, read Richard Talcott's "Cassini spies Phoebe" (*Astronomy*, September 2004). For more on the spacecraft's flights past Jupiter in late 2000 and early 2001, check out Talcott's "A giant awakens Cassini" (*Astronomy*, April 2001). Also see planetary scientist Alfred S. McEwen's "Journey to Saturn" (*Astronomy*, January 2004). McEwen, a member of the Cassini imaging team, presents the mission's top-ten highlights.

WEB — The official web sites of Cassini and Huygens are the best sources for news on mission progress. NASA's site, which focuses on the Cassini orbiter, resides at *saturn.jpl.nasa.gov/index.cfm*. The European Space Agency's site for the Huygens probe is located at *sci.esa.int/science-e/www/area/index.cfm?fareaid=12*.

STAR-SPLITTING JETS OF SUPERNOVAE

BOOKS — For a look at gamma-ray bursts by one of today's best known astrophysicists, read Craig Wheeler's *Cosmic Catastrophes: Supernovae, Gamma-Ray Bursts, and Adventures in Hyperspace* (Cambridge University Press, New York, 2000). *The Biggest Bangs: The Mystery of Gamma-Ray Bursts, the Most Violent Explosions in the Universe* by Jonathan I. Katz (Oxford University Press, New York, 2002) is a fascinating account into the workings of these exotic phenomena.

WEB — Visit the Supernova Science Center at *www.supersci.org* for the latest news plus a lot more from the world of gamma-ray bursts. Be sure to check out the movies — click the "Recent Results" button, and then click the "GRBs & XRBs" button. Another web site for your perusal is that of the High Energy Transient Explorer at *space.mit.edu/HETE*.

TOUTATIS SHOOTS PAST EARTH

BOOKS — For more on asteroid observing, see *Observing Comets, Asteroids, Meteors, and the Zodiacal Light* by Stephen J. Edberg and David H. Levy (Cambridge University Press, New York, 1994). For a general work on asteroid science, see Curtis Peebles's *Asteroids: A History* (Smithsonian Institution Press, Washington, D.C., 2000). The major resource for asteroid science is the thousand-page compendium of professional papers titled *Asteroids III* (University of Arizona Press, Phoenix, 2002) edited by William F. Bottke, Jr., et al. Another volume in the same series is *Hazards Due to Comets and Asteroids*, edited by Tom Gehrels (University of Arizona Press, Phoenix, 1994). Despite its age, much of the information in this volume remains useful and interesting. A book aimed more at beginners is Duncan Steel's *Rogue Asteroids and Doomsday Comets* (John Wiley & Sons, New York, 1995).

WEB — To get a good idea of what Toutatis probably looks like, check out Scott Hudson's web site at *www.eecs.wsu.edu/~hudson/Research/Asteroids/4179*. It contains images and spinning animations that Hudson developed by mathematically "inverting" the radar data on the asteroid. To explore what radar can do to take the measure of these microworlds, see Steve Ostro's web site at JPL: *echo.jpl.nasa.gov*; it prominently displays a Toutatis link.

Alain Maury hosts an interesting Toutatis web site at *www.astrosurf.com/maury/asteroids/toutatis.html*.

To learn more about NASA's program office for surveys of near-Earth objects (both asteroids and comets), check out *neo.jpl.nasa.gov/neo*. Tables of known close-approaching asteroids are located at *cfa-www.harvard.edu/iau/lists/CloseApp.html*. Finally, while sites devoted to Astérix appear to outnumber all other asteroids, a good place to start is *www.asterix.tm.fr*.

THE CALDWELL CATALOG

WEB — *Astronomy* contributing editor Alister Ling responds to Sir Patrick Moore's Caldwell Catalog, challenges the significance of Moore's list of objects, and offers his own list of deep-sky favorites at *members.aol.com/anonglxy/lingmoor.htm*.

The Astronomical League's Caldwell Club provides the Caldwell Catalog as it was published originally and awards those amateur astronomers who observe every object on the list. Check out this and other observing clubs, such as an urban observing club, constellation hunter club, and even a lunar club at *www.astroleague.org/al/obsclubs/obsclub.html*.

TWO TRANSIT TRIPS

WEB — Join *Astronomy* editor Dave Eicher, astronomers Jay Pasachoff and Fred Espenak, and Astronomical Tours on a two-week cruise of the Galapagos Islands for the total solar eclipse occurring April 8, 2005. To learn more about this trip and other exciting destinations, visit *www.astronomy.com/tours*.

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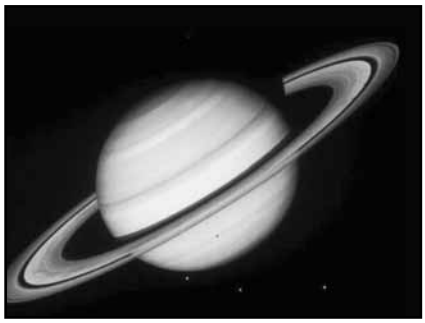
A natural teacher with a Ph.D. in astrophysics from Columbia University, Dr. Neil deGrasse Tyson has written prolifically for the public, including the series of essays in *Natural History* magazine on which this course is based. And though it was created for a lay audience and is readily accessible, the course is one in which science always takes precedence over drama. It is certainly entertaining, often funny, even awe-inspiring at times, as befits the subject matter. But clear introductions to essential principles of physics abound throughout these lectures, including density, quantum theory, gravity, and even the General Theory of Relativity. And Dr. Tyson also includes forays into disciplines such as chemistry and biology as needed to explain events.



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Saturn.

For example, Dr. Tyson begins one lecture at a point 13 billion years ago, when all space, matter, and energy in the known universe were contained in a volume less than one-trillionth the size of a pinpoint—about the size of an atom. By the time he finishes, the cosmos has been stretched, the planets and Earth formed, and 70 percent of Earth species wiped out by a gigantic asteroid—clearing the way for the evolution of humanity.

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About Your Teacher

Dr. Tyson (Ph.D., Columbia University) is Frederick P. Rose Director of the Hayden Planetarium at the American Museum of Natural History and Visiting Research Scientist and Lecturer at Princeton University. His recent books include a memoir, *The Sky is Not the Limit: Adventures of an Urban Astrophysicist* and *One Universe: At Home in the Cosmos* (co-authored with Charles Liu and Robert Irion), winner of the 2001 American Institute of Physics Science Writing Award to a Scientist.

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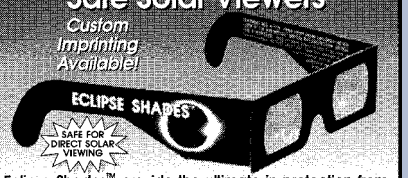

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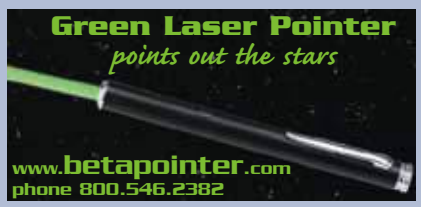

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Astronomy magazine

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Reader gallery

Readers share their images...

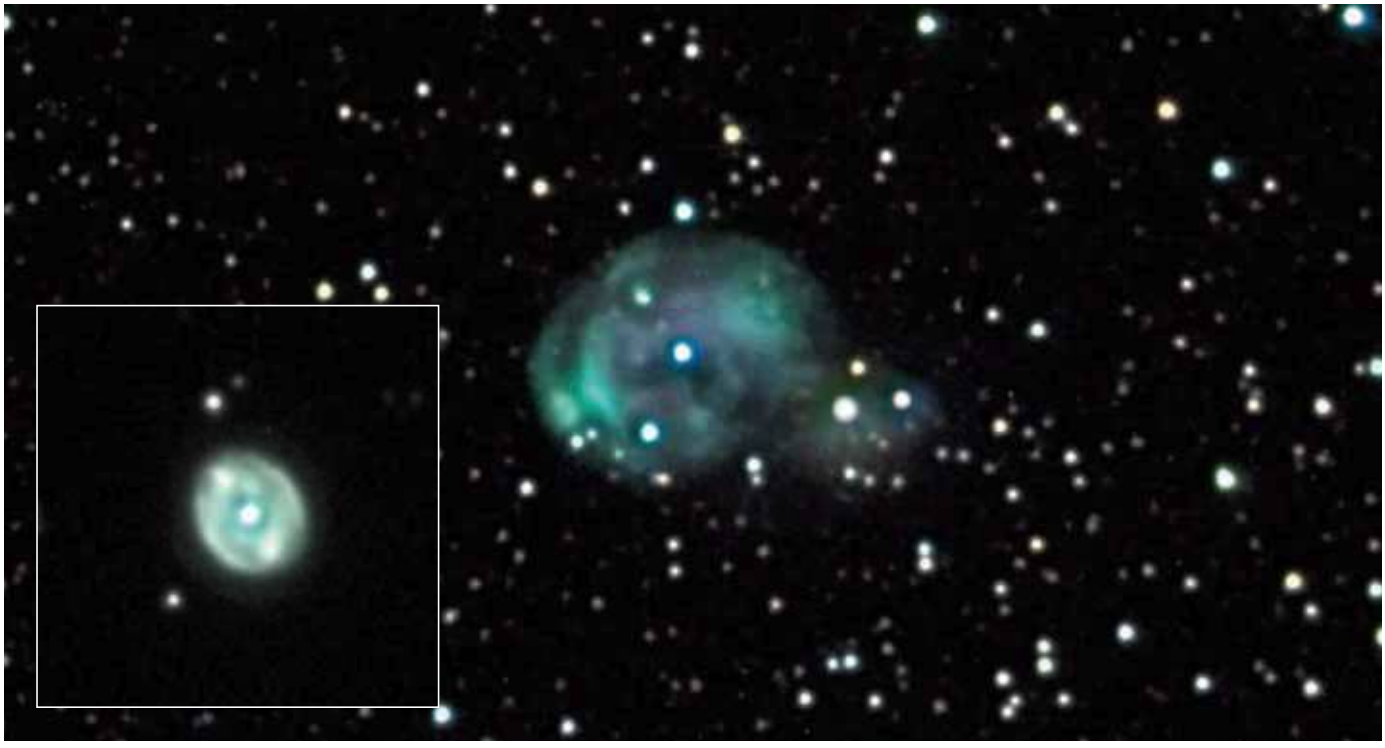
Star trails /// Markarian's Chain /// Planetary lineup /// Planetary nebulae
Bright and dark nebulae /// Jupiter /// The Moon /// Caldwell objects /// Globular cluster

CANYON STAR TRAILS (Olympus OM-1 35mm camera; 24mm lens at f/11; fixed tripod; Fuji Provia 100F film, 6 hour and 5 minute exposure; taken December 27-28, 2003, 6:15 P.M. to 12:20 A.M. PST; from Anza-Borrego Desert State Park, California) /// JOE ORMAN

SIMPLE ASTROPHOTOGRAPHY

Star trails from California

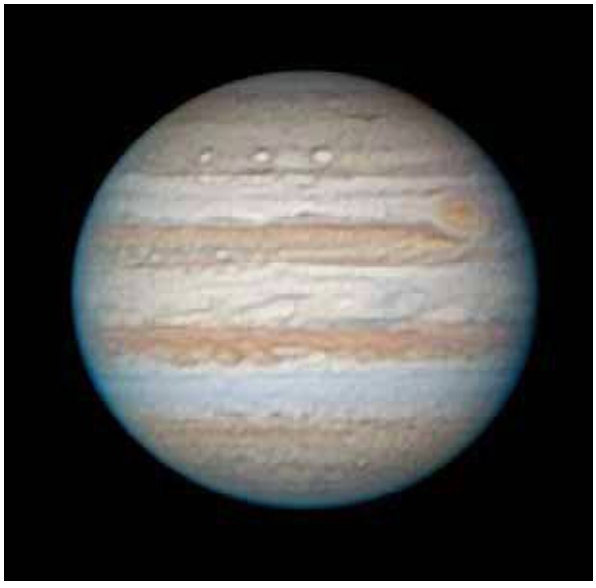
With a basic 35mm film camera, a cable release, a sturdy tripod, and a dark sky, you can produce stunning images that demonstrate Earth's rotation. Most of us know stars rise in the east and set in the west. This is true except near the north and south celestial poles. Around those two points, stars appear to move in circles, never rising or setting. Such stars are called circumpolar stars. To make such an image in the northern hemisphere, place Polaris (Alpha Ursae Majoris) at the center of your camera's field of view. Use the cable release to open and lock the shutter. The star trails will be more dramatic with a longer exposure.



Top left, MARKARIAN'S CHAIN OF GALAXIES (4-inch Borg apochromatic refractor at f/4, DTA C3 6303E CCD camera, LRGB image with exposures of 45, 9, 9, and 9 minutes, respectively) /// PAOLO CANDY

Top right, VENUS, MARS, AND SATURN LINE UP OVER SOFIA (Konica-Minolta A2 digital SLR, 28mm lens at f/4, 30-second tripod-mounted exposure, taken May 11, 2004, from Sofia, Bulgaria) /// VALERY HRISTOV

Bottom, PLANETARY NEBULAE NGC 6826 *(inset)* AND NGC 7008 (9½-inch Celestron Schmidt-Cassegrain telescope at f/10, SBIG ST2000XM CCD camera, LRGB image; exposures of 60, 15, 15, and 15 minutes, respectively) /// RICH JACOBS



Top, SHARPLESS 2-54 AND BARNARD 95 IN SERPENS (6-inch Astro-Physics f/7 EDF refractor, hypersensitized 120-format Kodak PPF Pro 400 film, two 45-minute exposures digitally combined) /// GEORGE GREANEY AND DEAN EASTON

Bottom left, JUPITER (11-inch Celestron Schmidt-Cassegrain telescope, ToUcam Pro 840 webcam, Tele Vue 3x Barlow lens, 456 1/33-second exposures, taken April 17, 2003, from Tierra Verde, Florida) /// JOSE SURO

Bottom right, THE GIBBOUS MOON (3-inch Borg 76ED apochromatic refractor, Sony F717 digital camera, 1/30-second exposure at ISO 100, eyepiece projection using a 20mm eyepiece, taken August 9, 2003, from Singapore) /// REMUS CHUA

Top left, CALDWELL 80 (NGC 5139) (16-inch Meade Schmidt-Cassegrain telescope at f/6.3, SBIG ST10XME CCD camera, LRGB image with exposures of 25, 10, 10, and 10 minutes, respectively, taken from Kitt Peak National Observatory) /// ADAM BLOCK

Top right, CALDWELL 46 (NGC 2261) (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST10XME CCD camera, LRGB image with exposures of 75, 20, 20, and 20 minutes, respectively, taken from Kitt Peak National Observatory) /// CAROLE WESTPHAL AND ADAM BLOCK

Bottom, CALDWELL 26 (NGC 4244) (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG ST10XME CCD camera, LRGB image with exposures of 90, 20, 20, and 20 minutes, respectively, taken from Kitt Peak National Observatory) /// JOE NAUGHTON, STEVE STAFFORD, AND ADAM BLOCK

Send your photos to: ASTRONOMY reader gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

Left, CALDWELL 33 (NGC 6992/5) (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST10XME CCD camera, 9-frame mosaic, each an LRGB image with exposures of 50, 10, 10, and 10 minutes, respectively, taken from Kitt Peak National Observatory) /// ADAM BLOCK, et al.

Top right, CALDWELL 47 (NGC 6934) (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST10XME CCD camera, LRGB image with exposures of 40, 10, 10, and 10 minutes, respectively, taken from Kitt Peak National Observatory) /// DALE NIKSCH AND ADAM BLOCK

Above, CALDWELL 45 (NGC 5248) (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST10XME CCD camera, LRGB image with exposures of 90, 20, 20, and 20 minutes, respectively, taken from Kitt Peak National Observatory) /// DALE NIKSCH AND ADAM BLOCK

Below, GLOBULAR CLUSTER NGC 6541 AND REFLECTION NEBULA NGC 6729 (4-inch Pentax SDP105 refractor, Starlight X-press SXV-H9 CCD camera, LRGB image with exposures of 4,300; 2,300; 800; and 1,500 seconds, respectively) /// GERALD RHEMANN AND MICHAEL JÄGER

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